AD-A285 944

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ARPA PROGRESS REPORT

CLEARED
FOR OPEN PUBLICATION

OCT 26 1994 12

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW (OASD-PA)
DEPARTMENT OF DEFENSE

REVIEW OF THIS MATERIAL DOES NOT IMPLY DEPARTMENT OF DEFENSE INDORSEMENT OF FACTUAL ACCURACY OR OPINION.

D. MIKLOVIC

26 AUGUST 1993

DTIC
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CONTRACT NO.: MDA972-91-C-0063

ARS-235-037-B

55 pg

94-34199

DTIC QUALITY INSPECTED 3

94 11 2 084

Areté Associates

P.O. BOX 8050, LA JOLLA, CALIFORNIA 92038

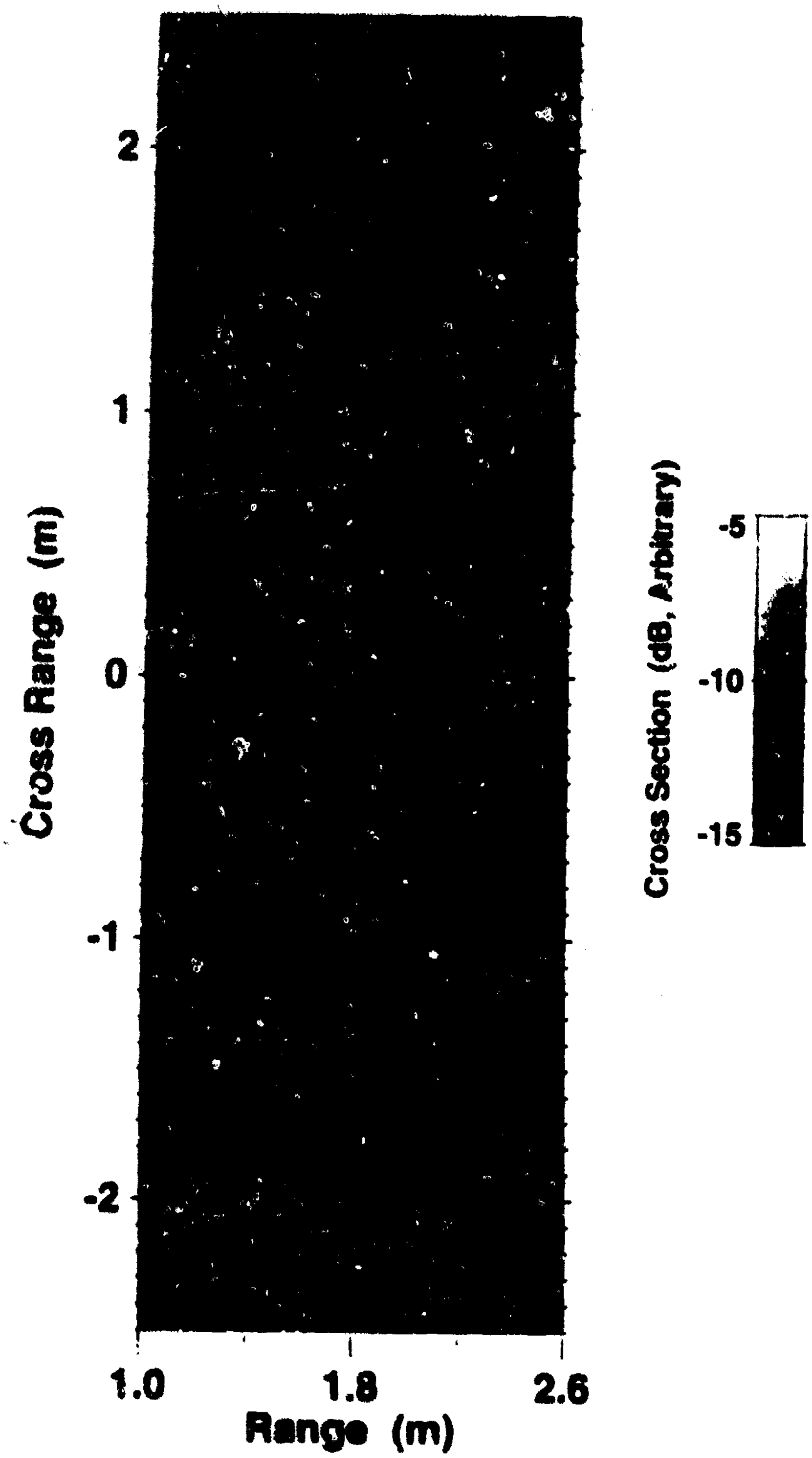
TOPICS

- Exploitation of Acoustic Color for Classification
  - / Explosive sources
  - / Multiple transmitters
- Broadband Detection Assessment
  - / Optimal detector design
  - / Measurement based predictions
  - / Model based predictions
- Image Looping
  - / System motion
  - / Environmental interpretation
  - / Tracking
- Auto-coherence with Near Field Point Sources of Uncertain Location
  - / Fixed large aperture arrays
  - / Free floating sonobuoys
- Auto-coherence for Moving Arrays
  - / Left-right resolution
  - / Incoherent ping combination
- Processor Throughput Status

Accesion For	
NTIS CRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and / or Special
A-1	

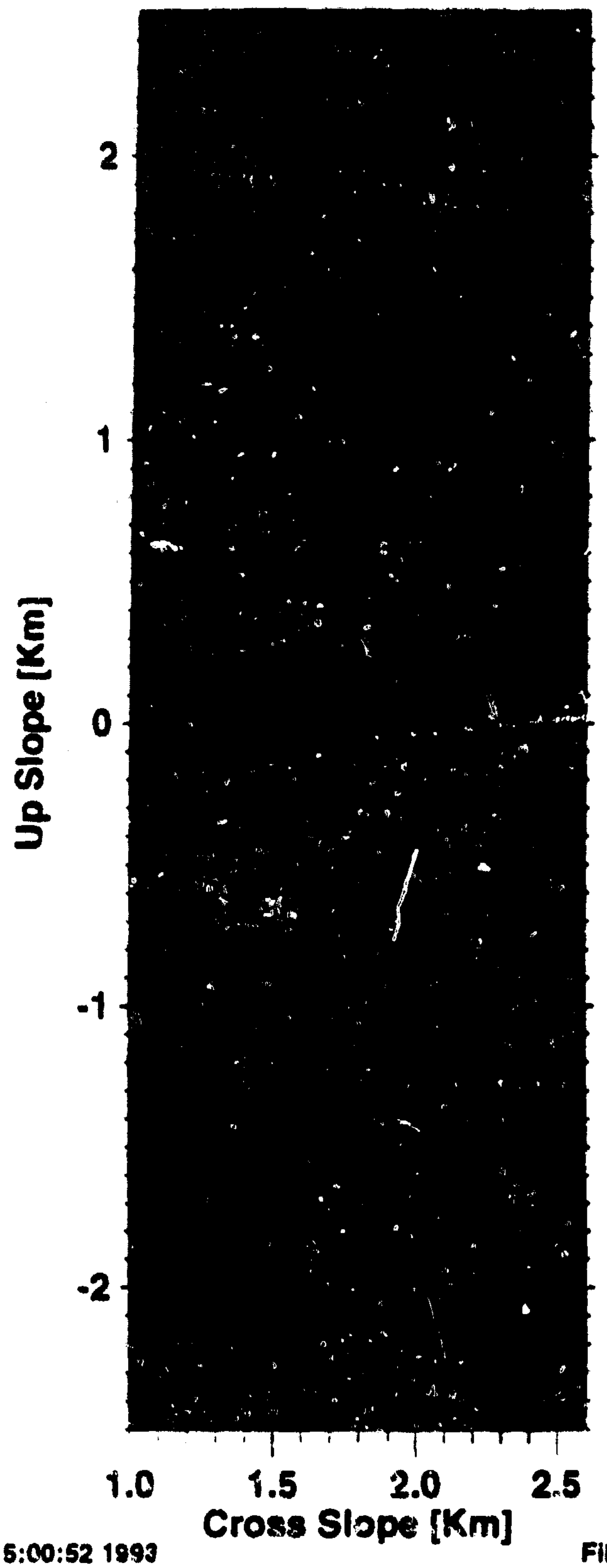
ARS-235-037-B

CST7, Low Wind (4 m/s)
Sum of Three Passbands



ARS-235-037-B

Surface Reverberation Spectral Color
Low Wind (4 m/s), CST7

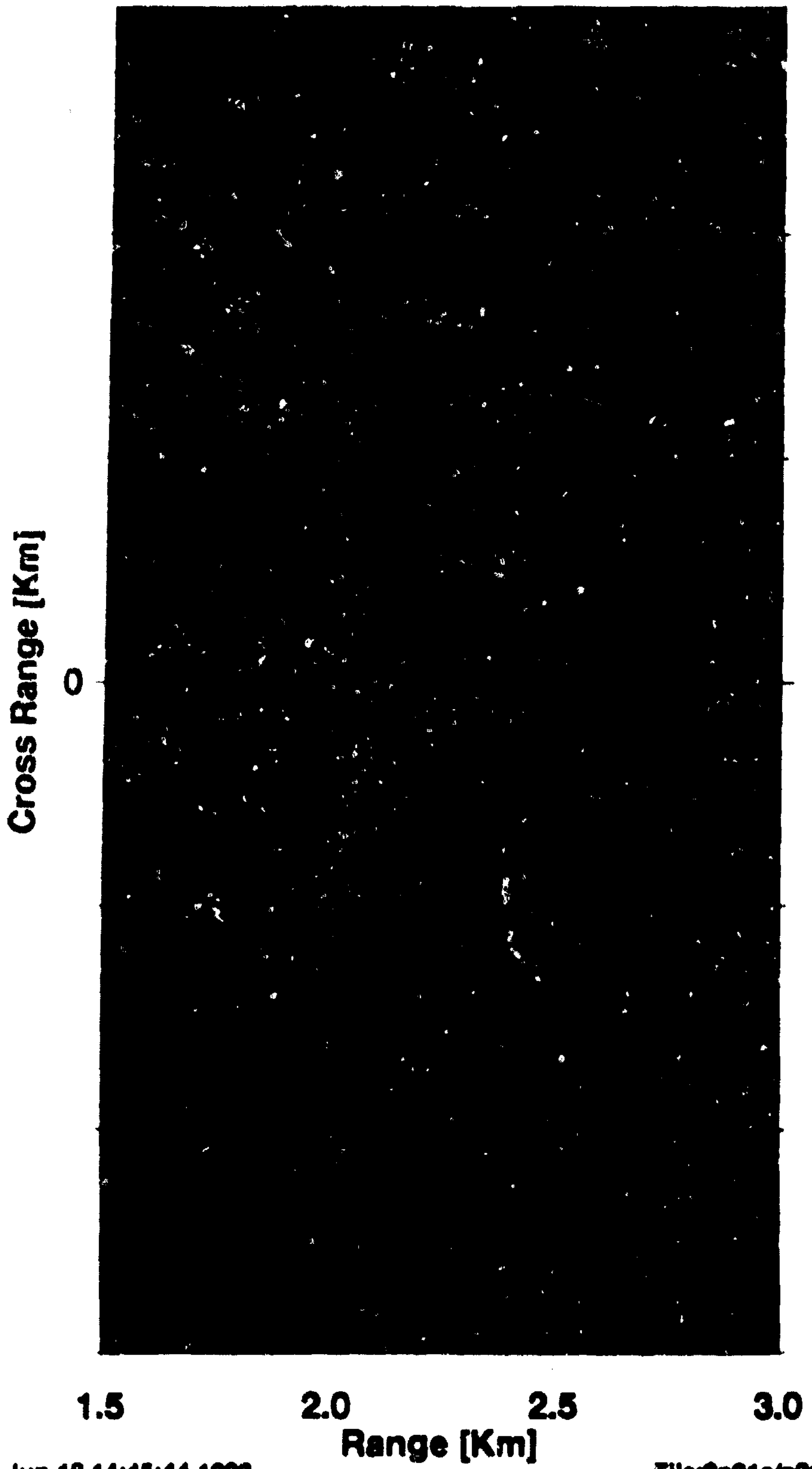


Fri Apr 16 15:00:52 1993

File:~/hs25c1/hs25c1.allband.ps

ARS-235-037-B

Acoustic Color For Bottom Clutter
Depth: 80 Fathoms

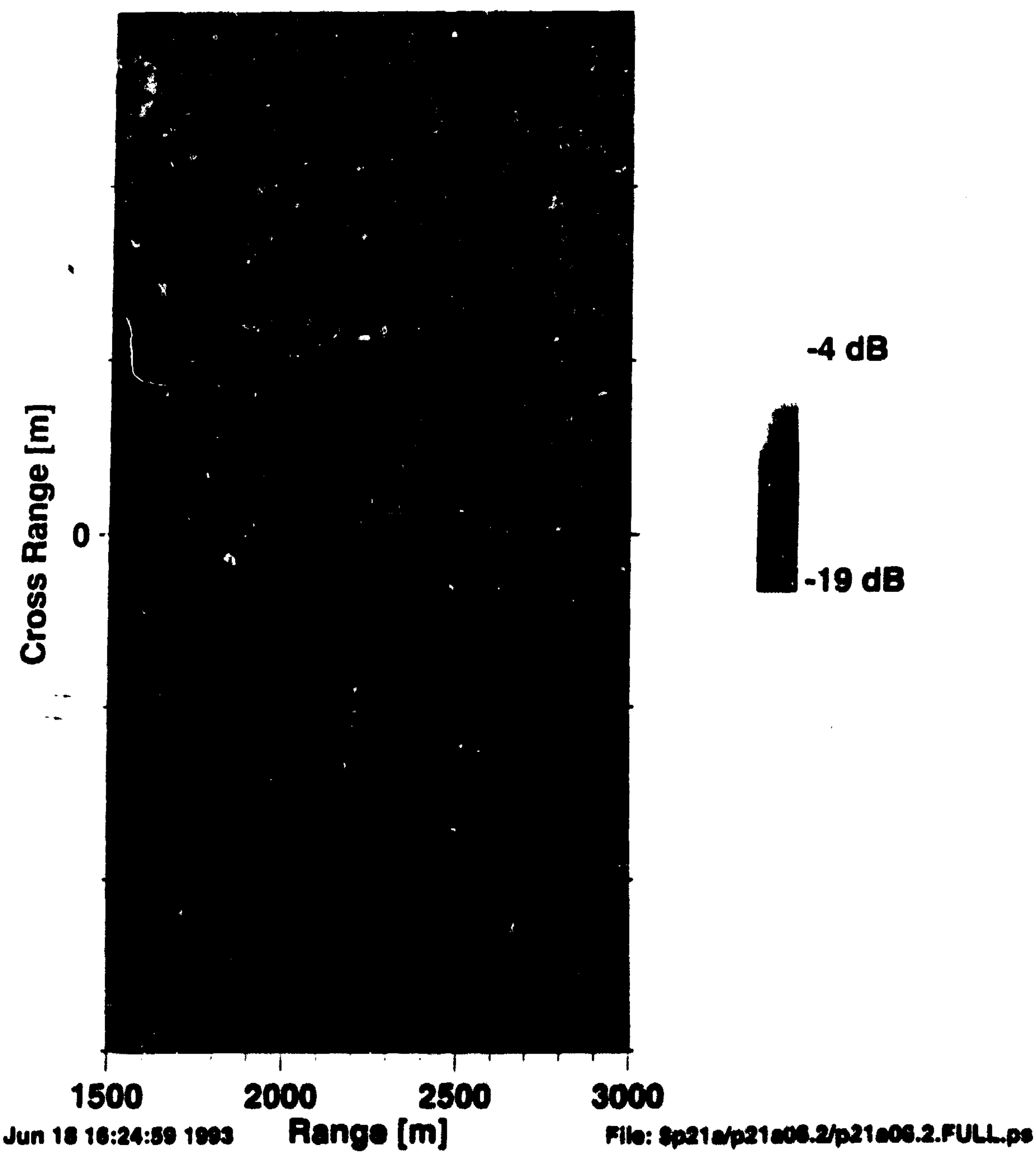


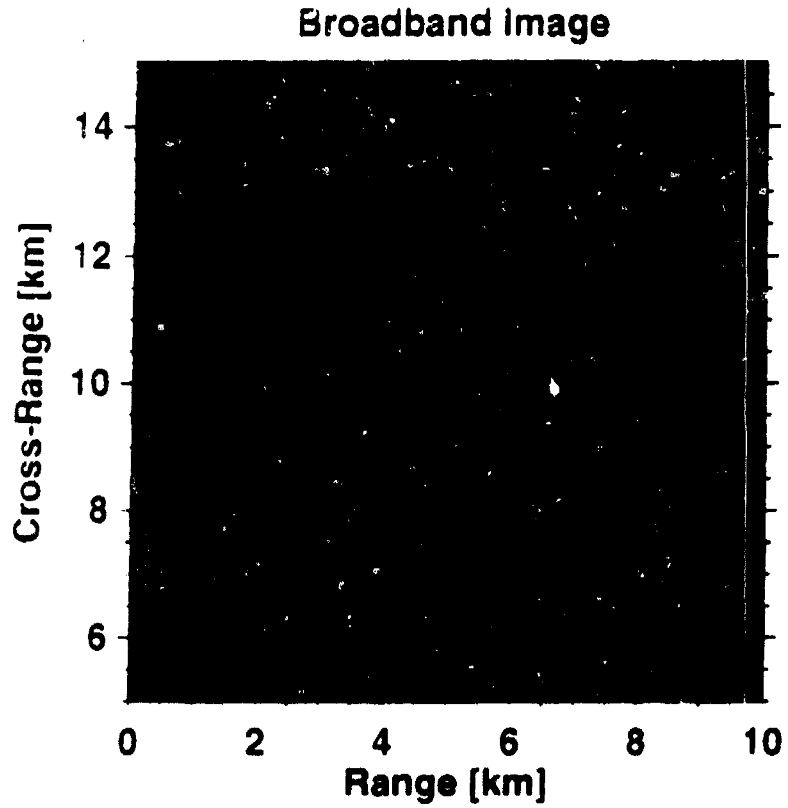
Fri Jun 18 14:45:44 1993

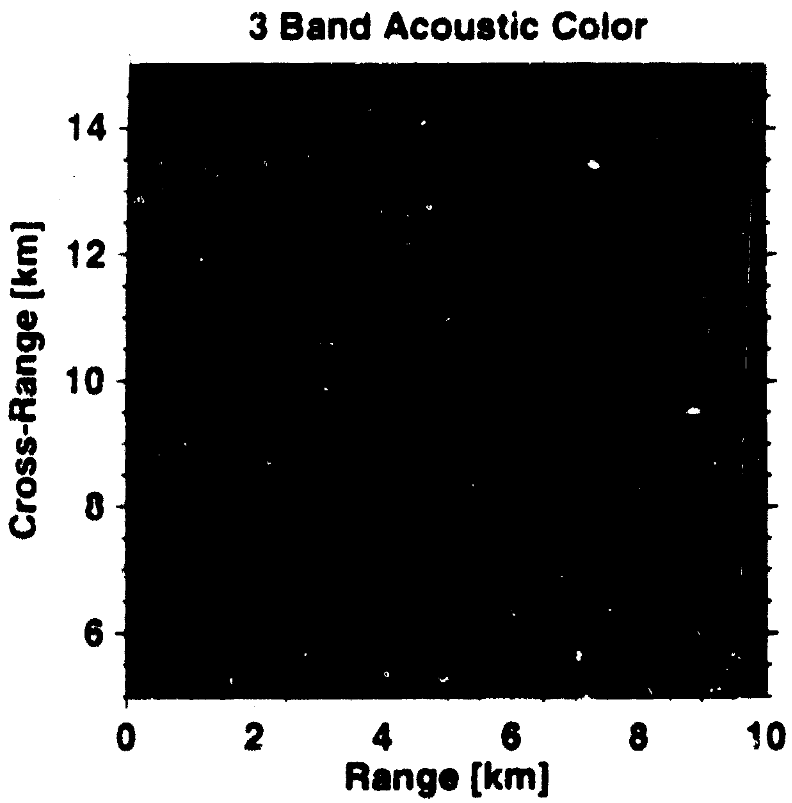
File:$p21a/p21a06.2/p21a06.2.Cl.ps

ARS-235-037-B

Broadband Image For Bottom Clutter
Depth: 80 Fathoms

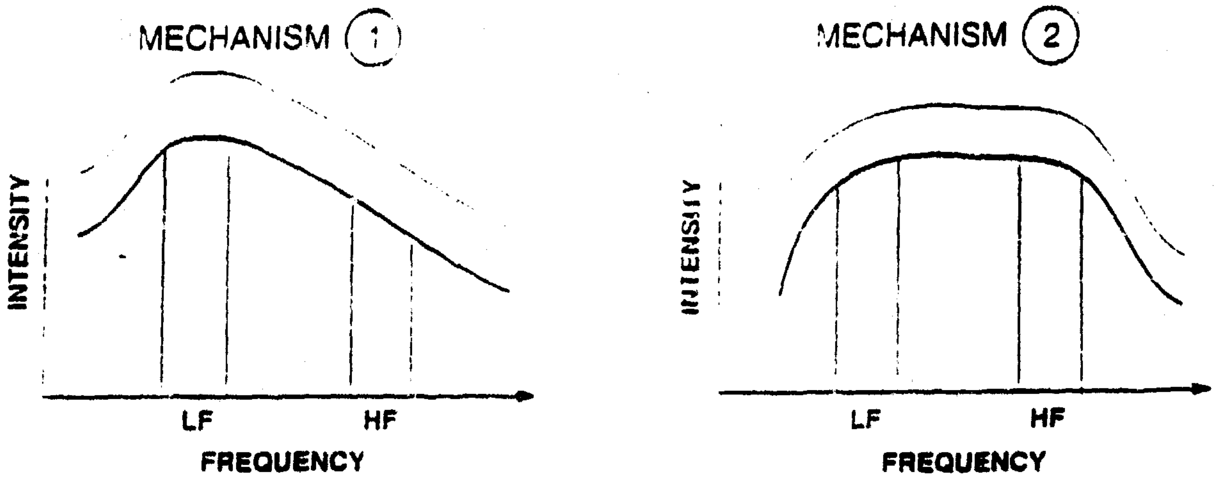



Broadband Image
14
12
10
8
6
Cross-Range [km]
0
2
4
6
8
10
Range [km]

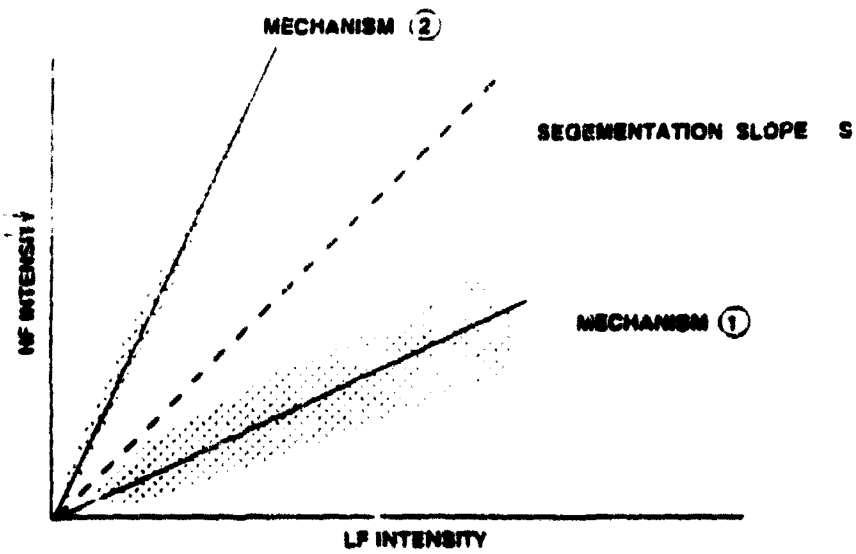

3 Band Acoustic Color
14
12
10
8
6
Cross-Range [km]
0
2
4
6
8
10
Range [km]

plot2.ps

SCATTERING MECHANISM SEGMENTATION BASED ON SPECTRAL SHAPE



MULTIBAND PIXEL SCATTERGRAM

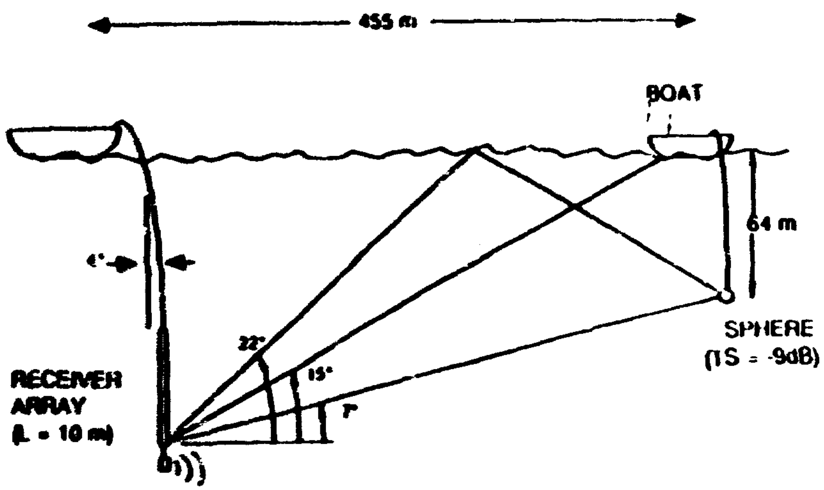


$\frac{HF}{LF} < S$ Classify as 1

$\frac{HF}{LF} > S$ Classify as 2

TARGET DISCRIMINATION USING BROADBAND SIGNALS

BOAT/SPHERE SCATTERING GEOMETRY



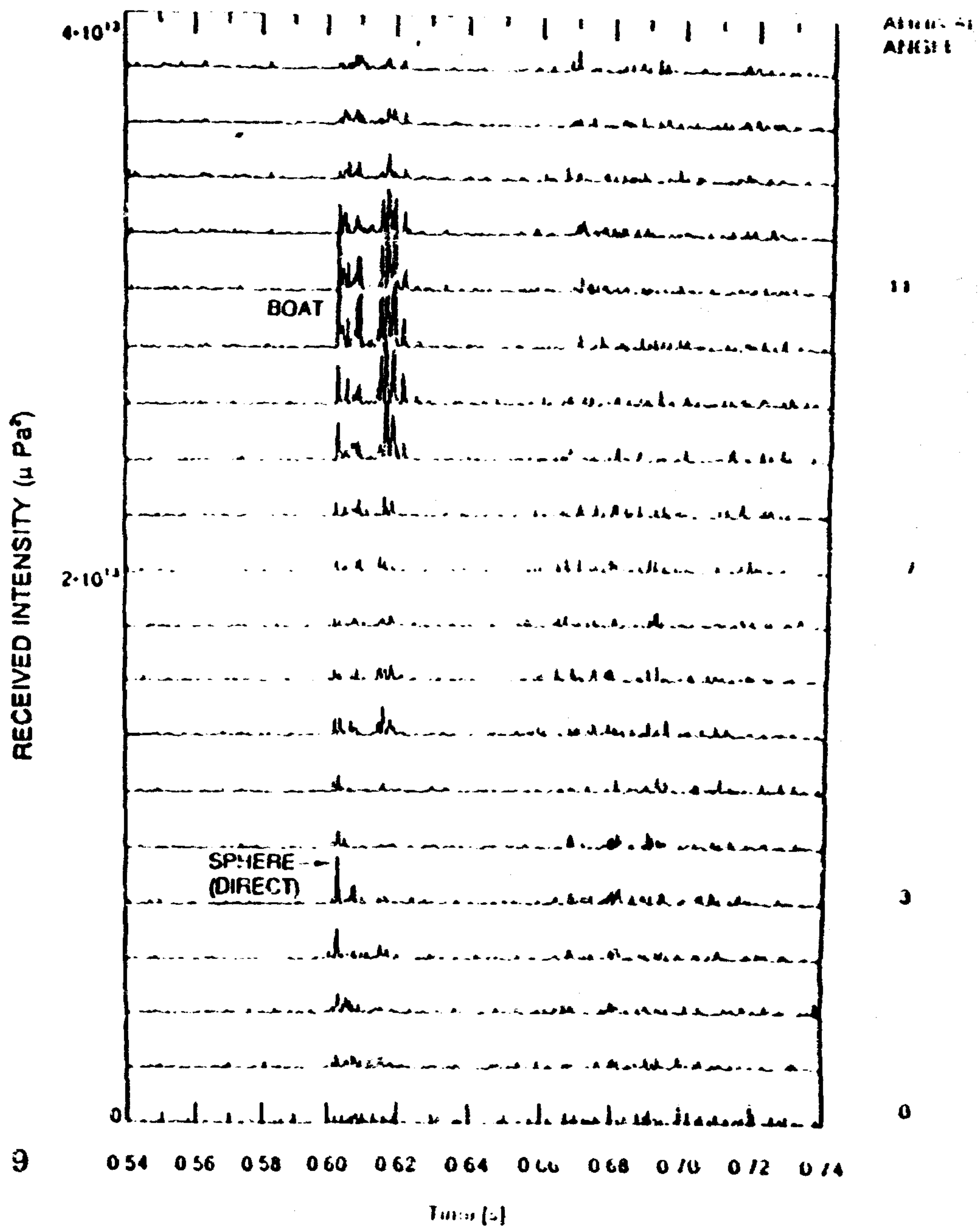
ARRAY RESOLUTION

N = 8 HYDROPHONES, L = 10 m, $\Delta\omega$ = 5 kHz

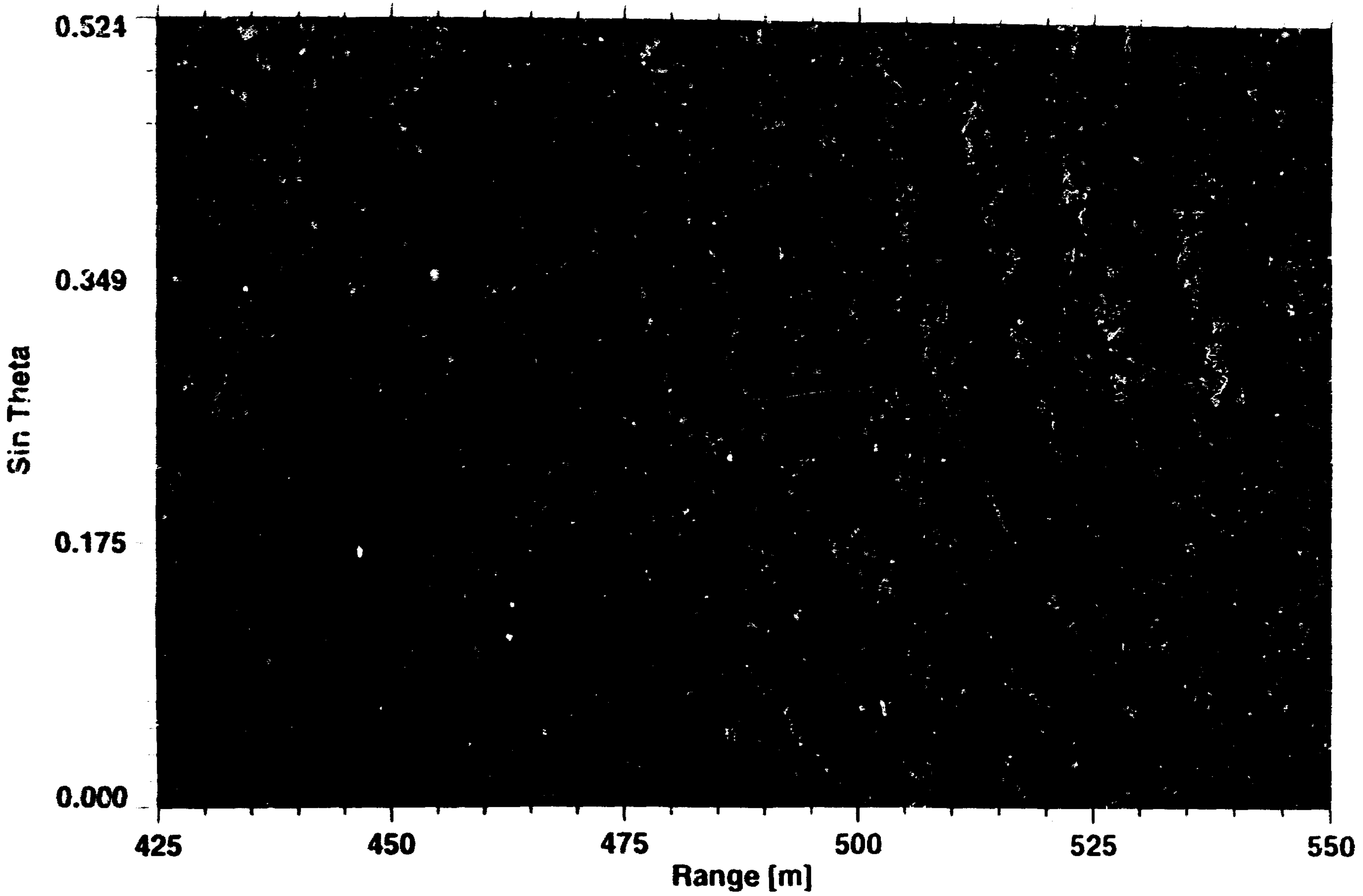
NARROW BAND: $\lambda/L = 14°$

BROADBAND: $\sqrt{2}\,\frac{C}{L\,\Delta\omega} = 2.4°$

TIME-ANGLE ARRIVAL STRUCTURE



Spectral Color Imaging



NARROW BAND VS. BROADBAND DETECTION

Relevant Parameters

noise (all non-target fluctuations) PSD:	$P_n(\omega)$
signal ESD:	$E(\omega)$
signal spread:	T

Narrowband

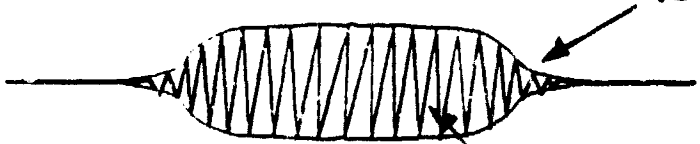
- No signal spread $\Rightarrow \Delta\omega\ T = 1$
- intuitively SNR is ratio of powers

$$SNR = \frac{2P_s\,\Delta\omega}{2P_n\,\Delta\omega} = \frac{E\,\Delta\omega}{TP_n\,\Delta\omega} = \frac{E\,\Delta\omega}{P_n}$$

Broadband

- **Parameters vary with frequency so that optimal combination of frequencies is an issue.**
- $\Delta\omega\ T > 1$ **due to target spread, so this must be factored into performance.**

SIGNAL MODEL



Signal : $s(t) = \sqrt{e}(t - a)\delta s(t)$

$\delta s(t)$ - colored Gaussian process with known PSD $P_S(\omega)$

$e(t)$ - deterministic "slowly varying" signal energy envelope

a - unknown signal position

OPTIMAL BROADBAND "ENERGY" DETECTOR

Likelihood ratio test on measurement m(t) leads to the following optimal energy detector:

a weighted square – law detector:

$$d(a) = \int_{-\infty}^{\infty} m_f^2(t)\, e(t-a)\, dt$$

with the linear filter:

$$m_f(t) = \int \frac{M(\omega)}{P_n^{1/2}} \left(\frac{P_s}{P_s + P_n} \right)^{1/2} e^{i2\pi\omega t}\, d\omega$$

$$M(\omega) = \int m(t)\, e^{-i2\pi\omega t}\, d\omega$$

P_n = noise PSD , P_s = signal PSD

The filter power transfer function is

$$|H|^2 = \frac{1}{P_n} \bullet \frac{P_s}{P_s + P_n}$$

NOISE WHITENER

OPTIMAL FREQUENCY WEIGHTING

SNR FOR THE OPTIMAL DETECTOR

Standard detector power SNR is $\dfrac{\left(d_{s+n} - d_n\right)^2}{\mathrm{var}(d_n)}$.

This can be expressed exactly as

$$SNR_E = \frac{1}{2T} \frac{\left(\displaystyle\int \frac{E^2(\omega)}{P_n(P_s + P_n)} d\omega \right)^2}{\displaystyle\int \left(\frac{E(\omega)}{P_s + P_n} \right)^2 d\omega}$$

where

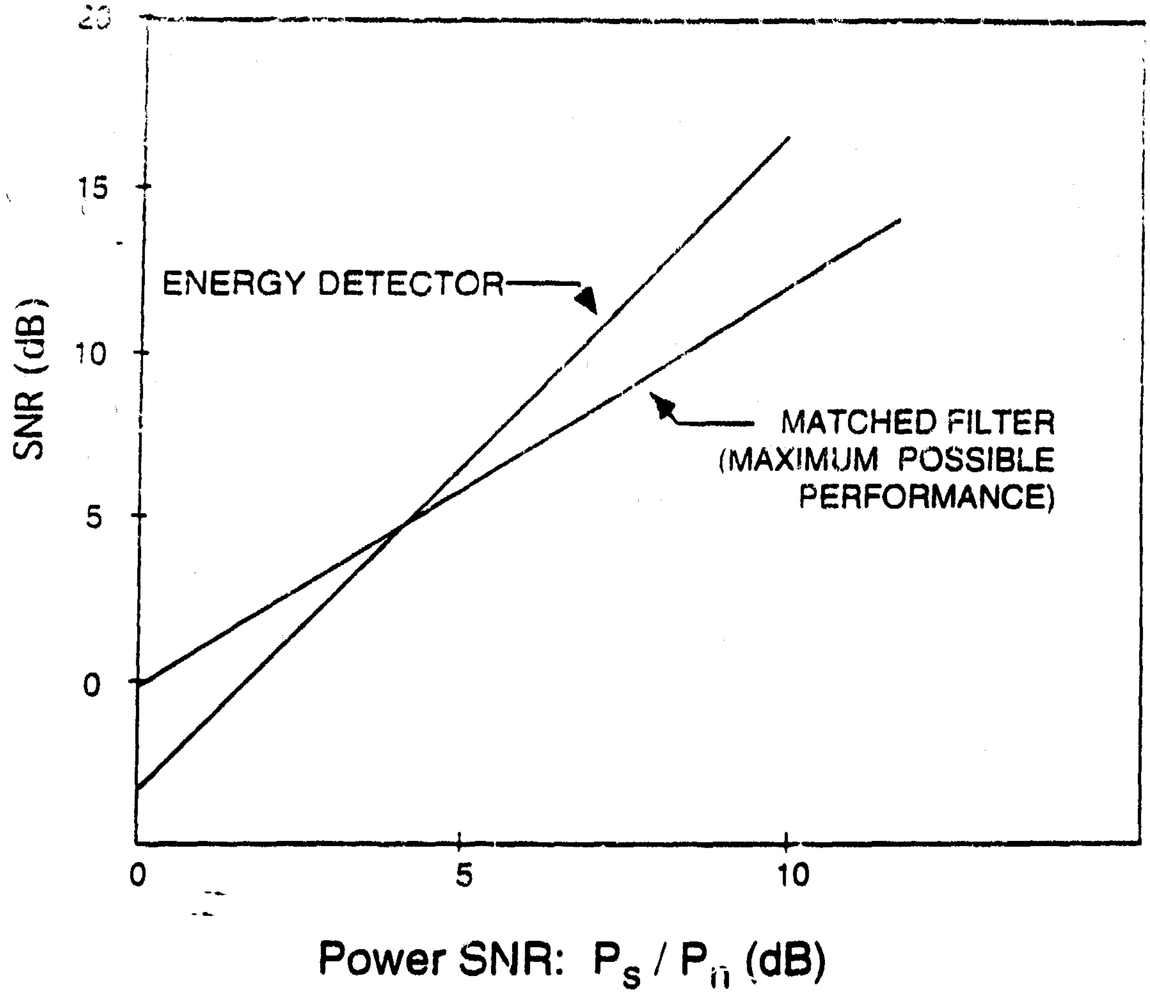
$$T = \frac{(\int e\,dt)^2}{\int e^2\,dt} \qquad P_s = \frac{E}{T}$$

for small signal power, and small bandwidth

$$SNR_E \rightarrow T\Delta\omega \left(\frac{P_s}{P_n} \right)^2$$

The usual result for energy detection (e.g. Urick case II).

DETECTOR SNR VS. POWER SNR



⇒ energy detector SNR poor measure of performance for $P_s / P_n \geq 0$ dB.

FIGURE OF MERIT

- A figure of merit must be interpretable in terms of ROC performance.

- A useful bound is:

  for $P_D \cong 1/2$, $\quad P_{FA} \leq e^{-\lambda_1} P_D$

  where λ_1 = < log-likelihood in signal and noise >.

- For the classical matched filter

  $$\lambda_1 = 1/2 \text{ SNR}$$

  therefore $2\lambda_1$ is the appropriate SNR-like figure of merit.

- This can be expressed analytically

$$2\lambda_1 = T \int \left[\frac{P_s}{P_n} - \log\left(1 + \frac{P_s}{P_n}\right) \right] d\omega$$

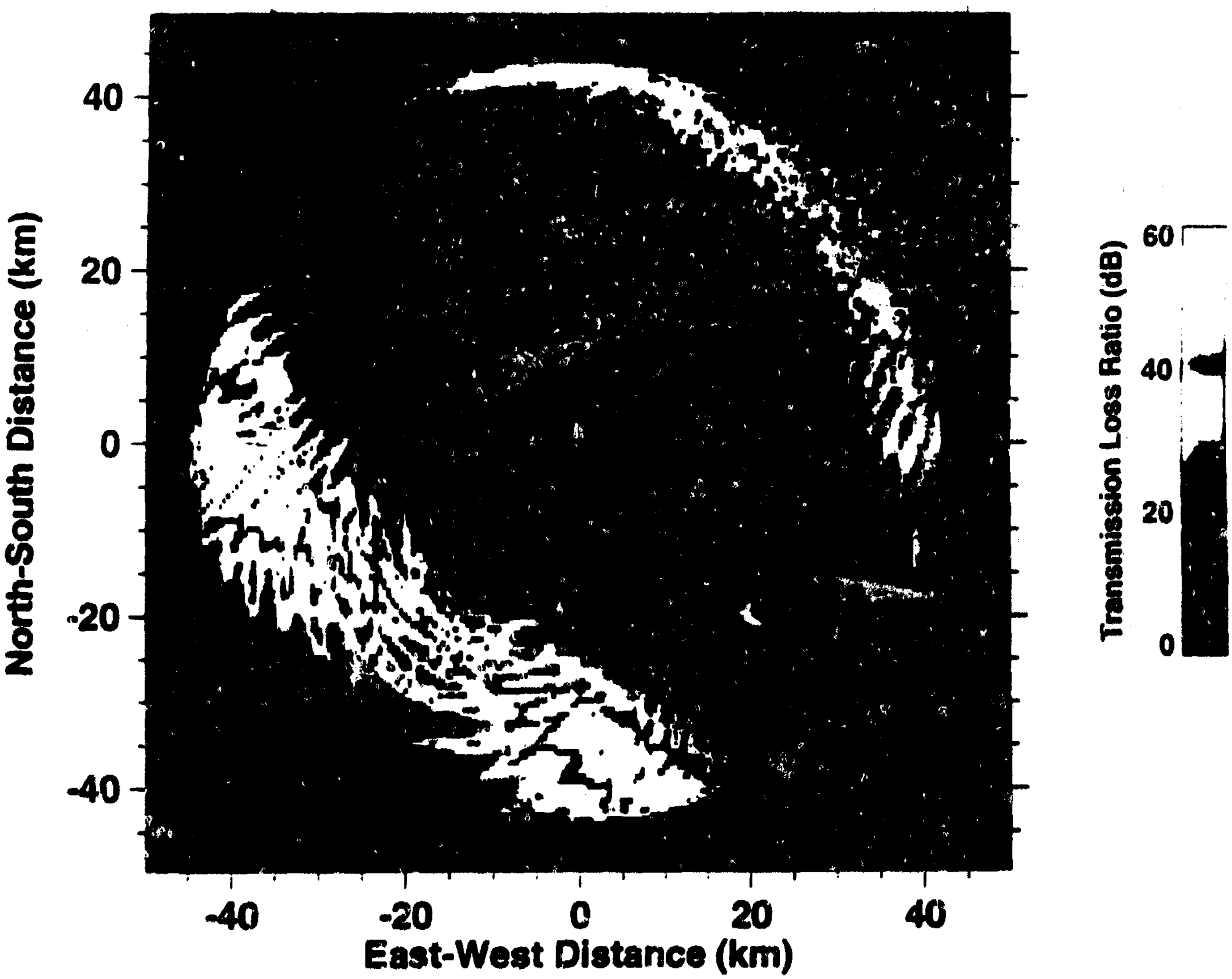
where

$$T = \frac{\left(\int e\,dt\right)^2}{\int e^2\,dt} \qquad P_s = \frac{E}{T}$$

ARS-235-037-B

ACT1 Simulation: Ratio of Target TL to Bottom TL

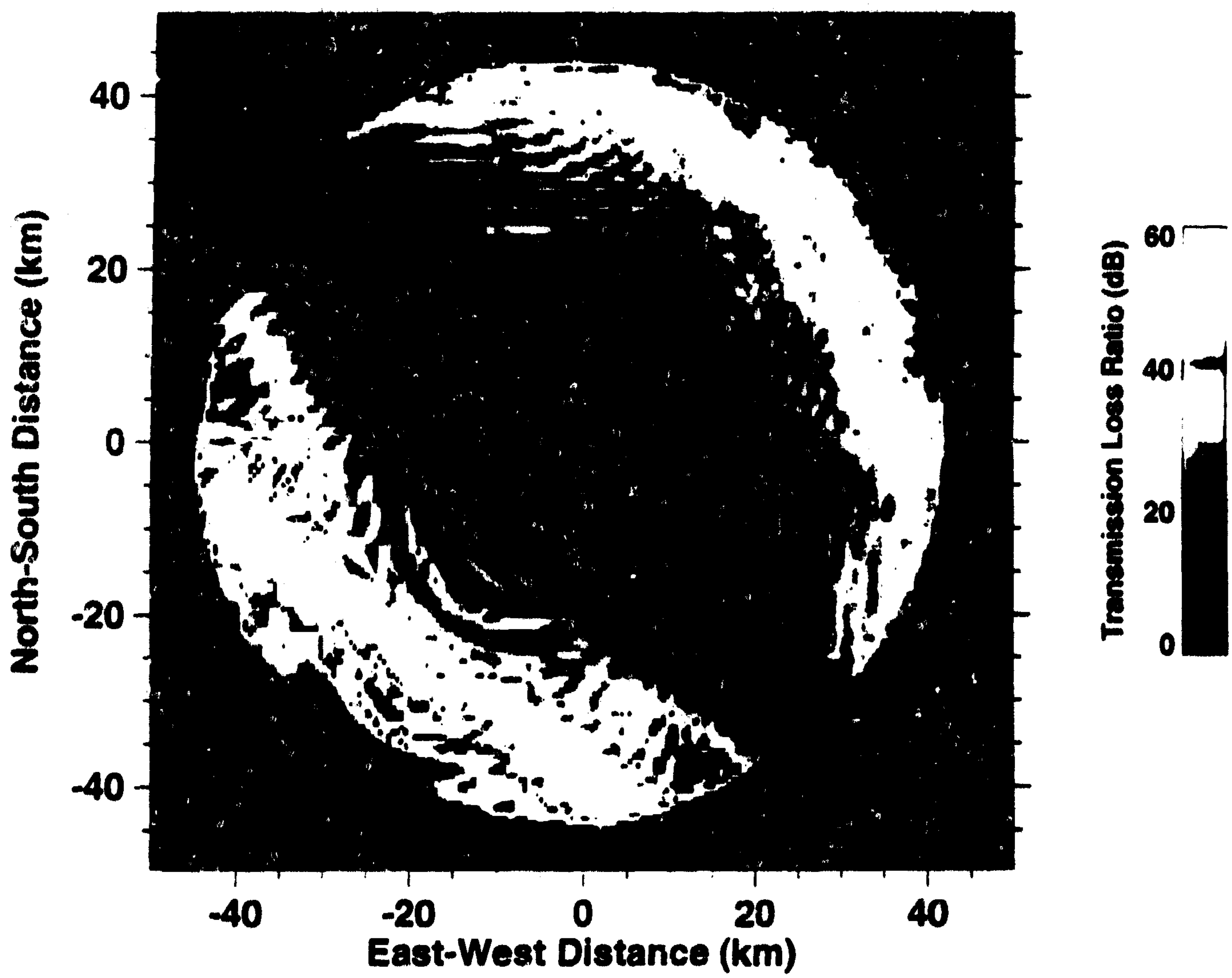
200 Hz Omni Source, Bottomed Array
20 m Target Depth



ARS-235-037-B

ACT1 Simulation: Ratio of Target TL to Bottom TL

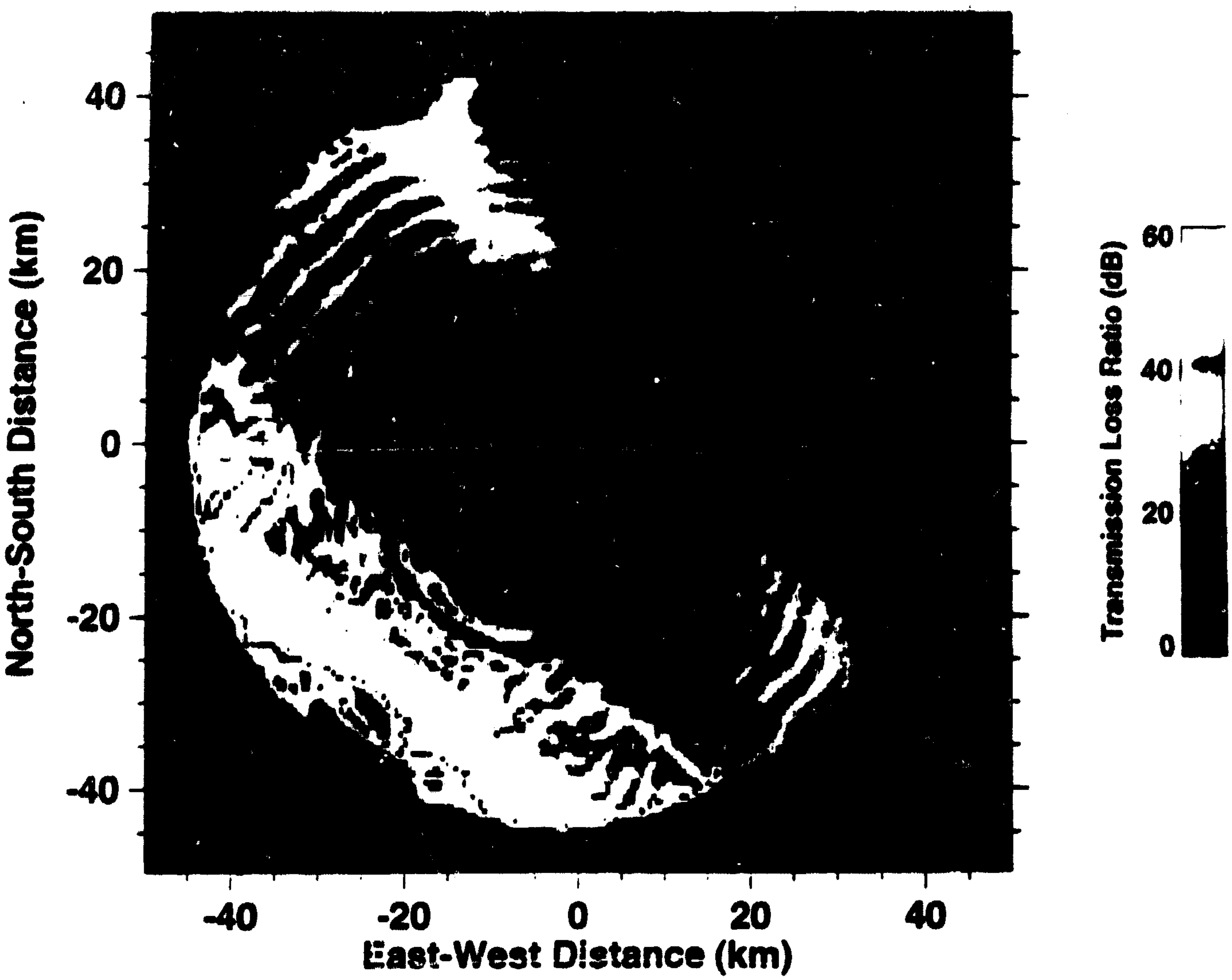
200 Hz Omni Source, Bottomed Array
40 m Target Depth



ACT1 Simulation: Ratio of Target TL to Bottom TL

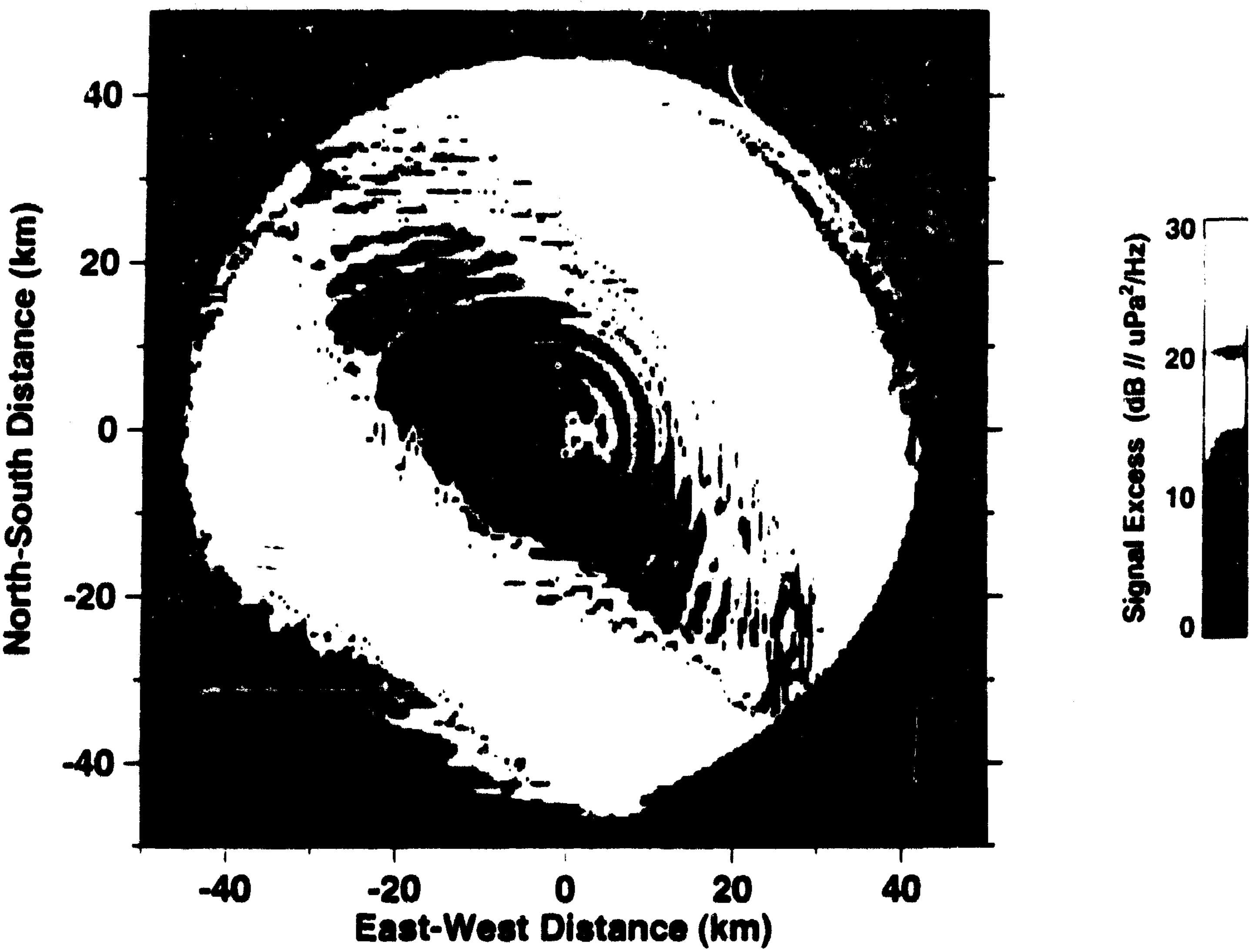
200 Hz Omni Source, Bottomed Array

80 m Target Depth



ARS-235-037-B

ACT1 Figure of Merit Simulation
Omni Source
Target Depth=40 m, Target Strength=5 dB

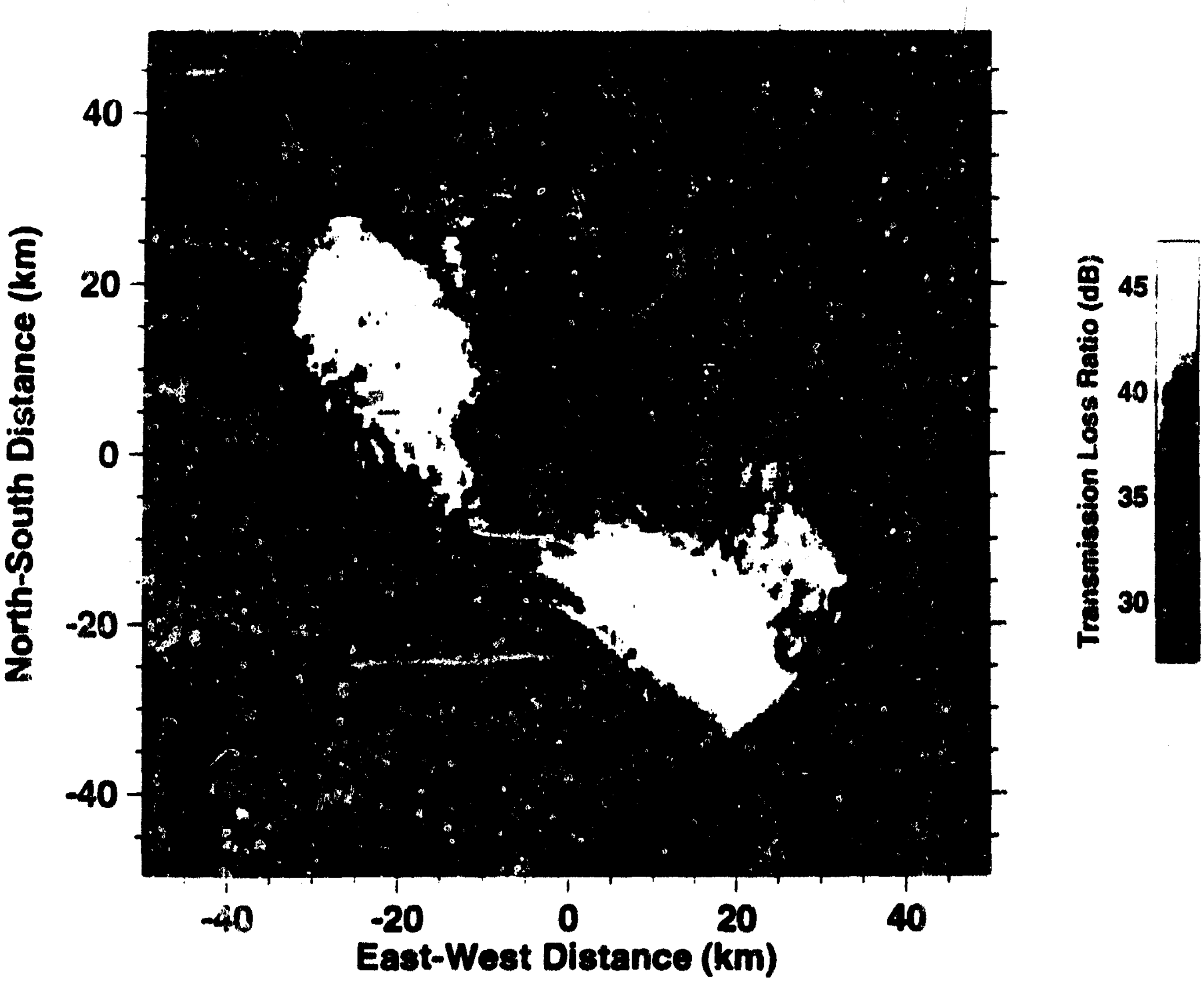


Tue Aug 24 18:02:20 1993

fom.sim.omni.40m.bb.ps

ARS-235-037-B

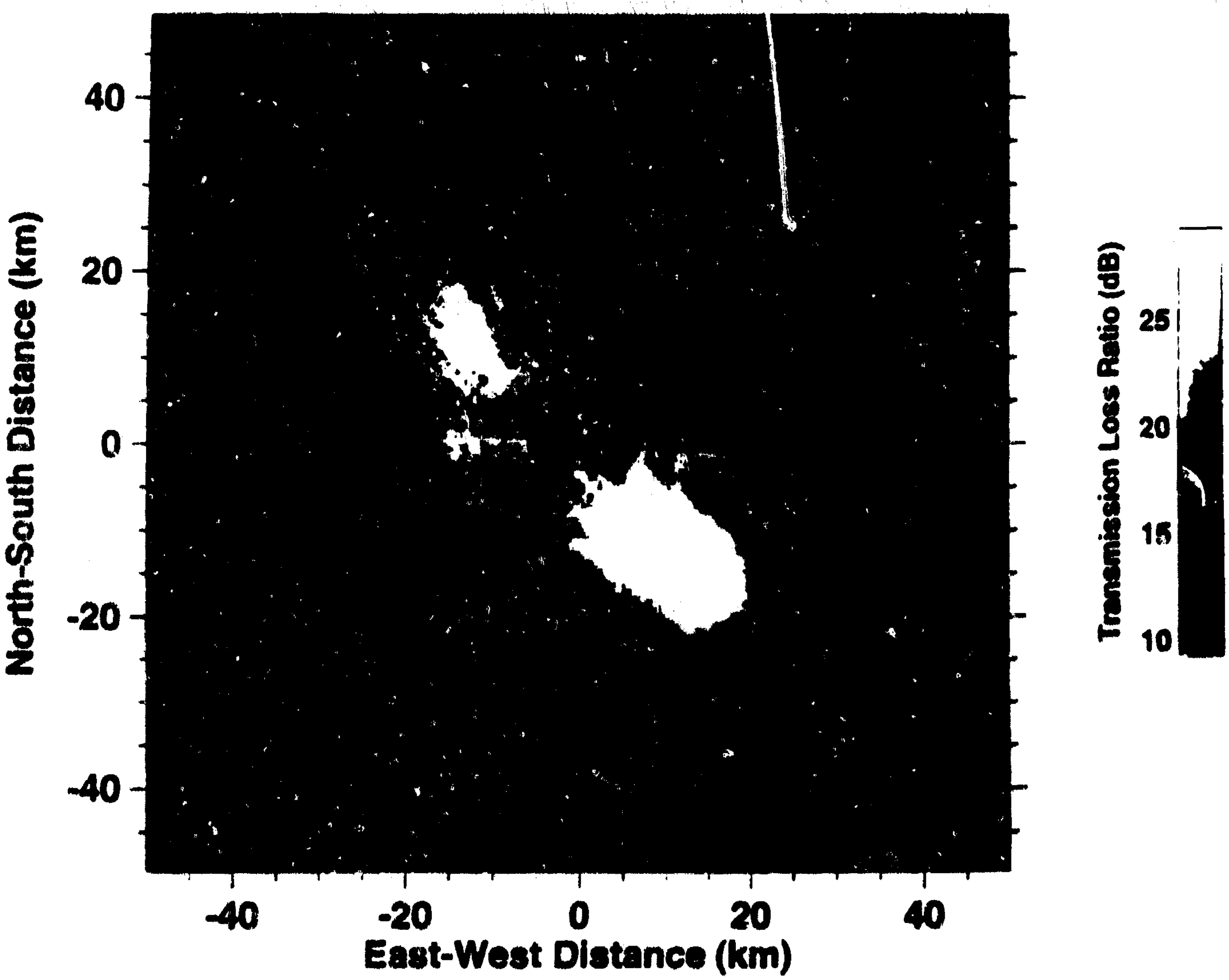
ACT1 Bottom Reverberation Level Simulation
Omni Source, Bottomed Array, 50 Hz
Includes Spherical Spreading Correction and Backscatter



ARS-235-037-B

ACT1 Bottom Reverberation Level Simulation

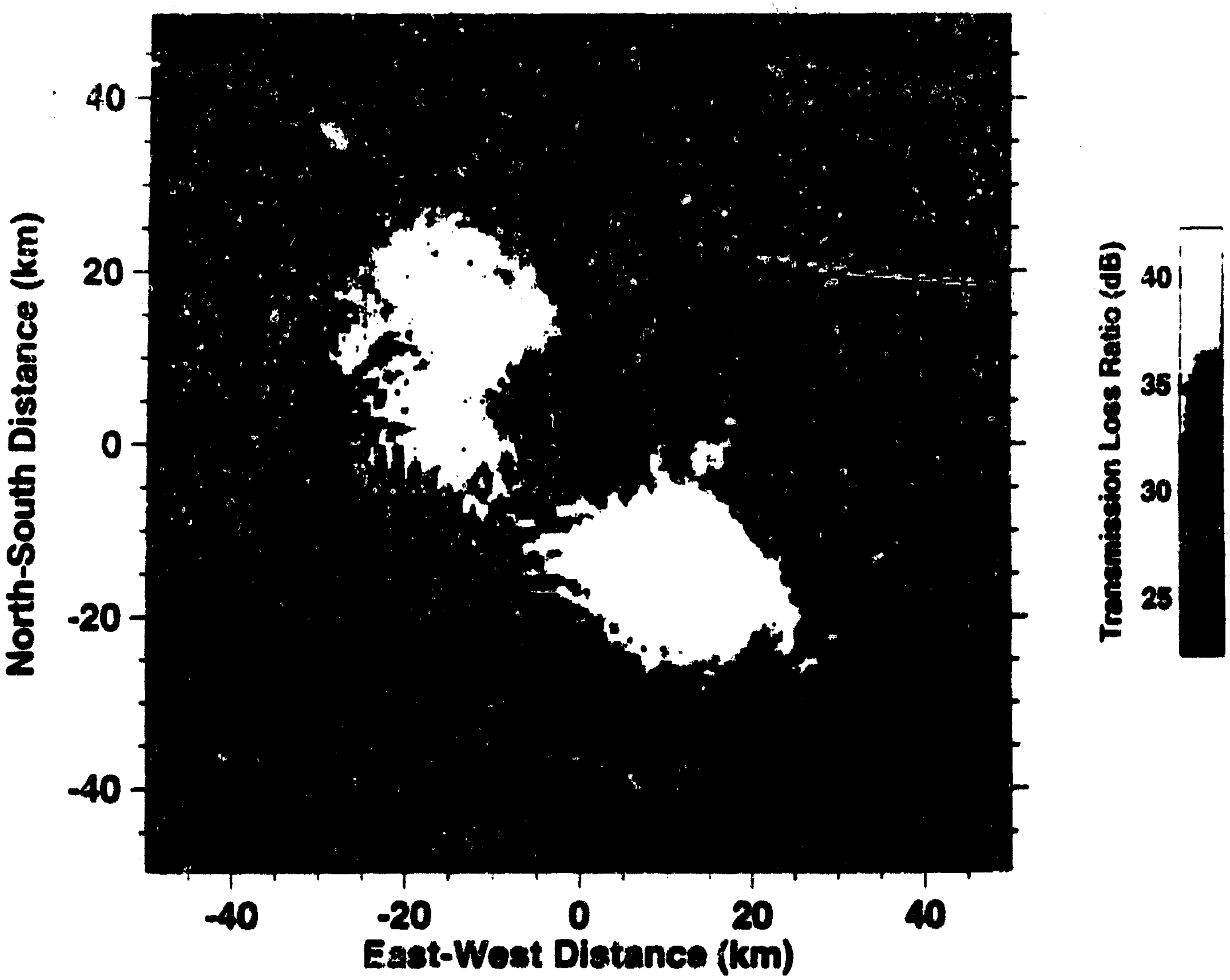
Omni Source, Bottomed Array, 200 Hz
Includes Spherical Spreading Correction and Backscatter



ARS-235-037-B

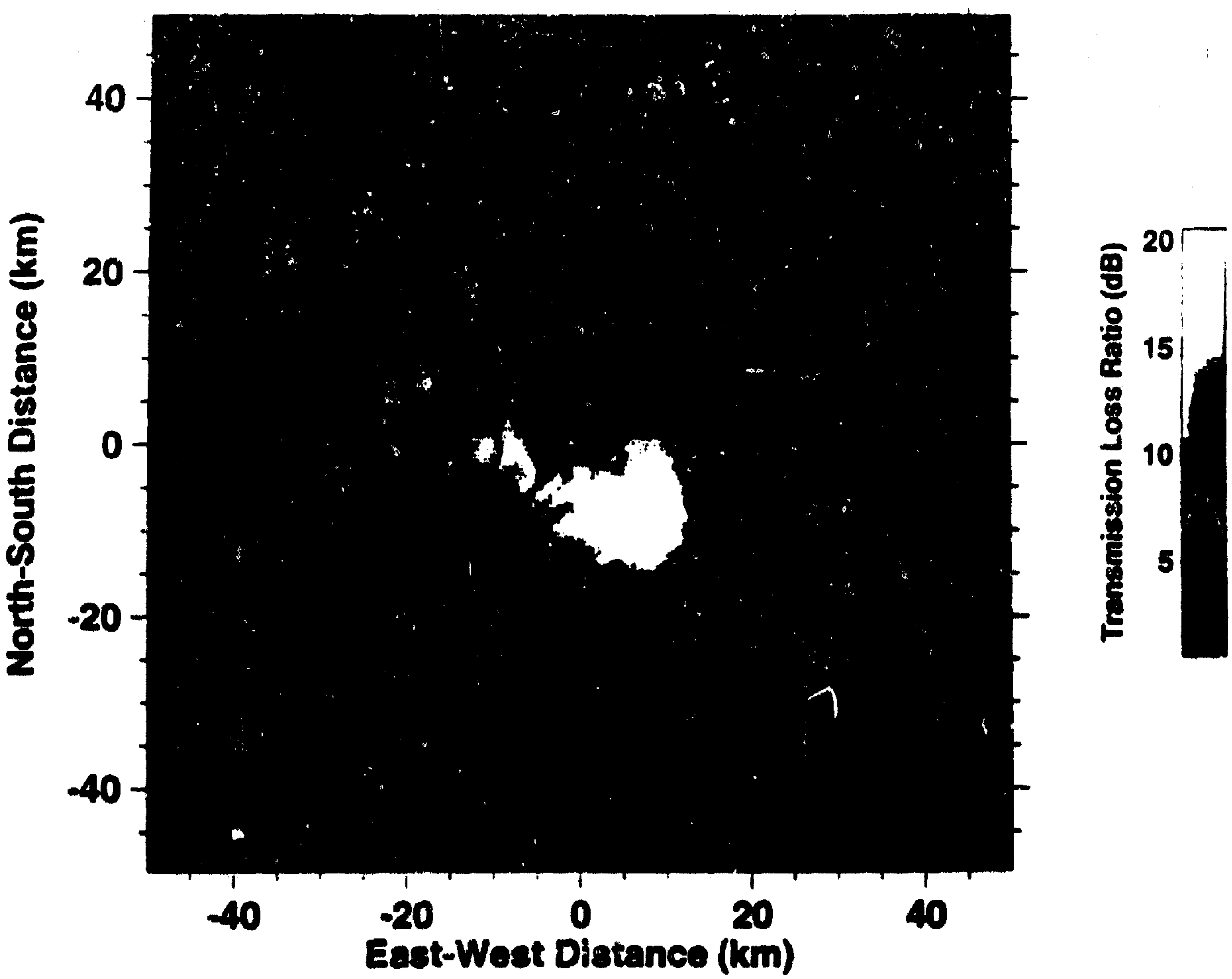
ACT1 Bottom Reverberation Level Simulation

Omni Source, Bottomed Array, 100 Hz
Includes Spherical Spreading Correction and Backscatter



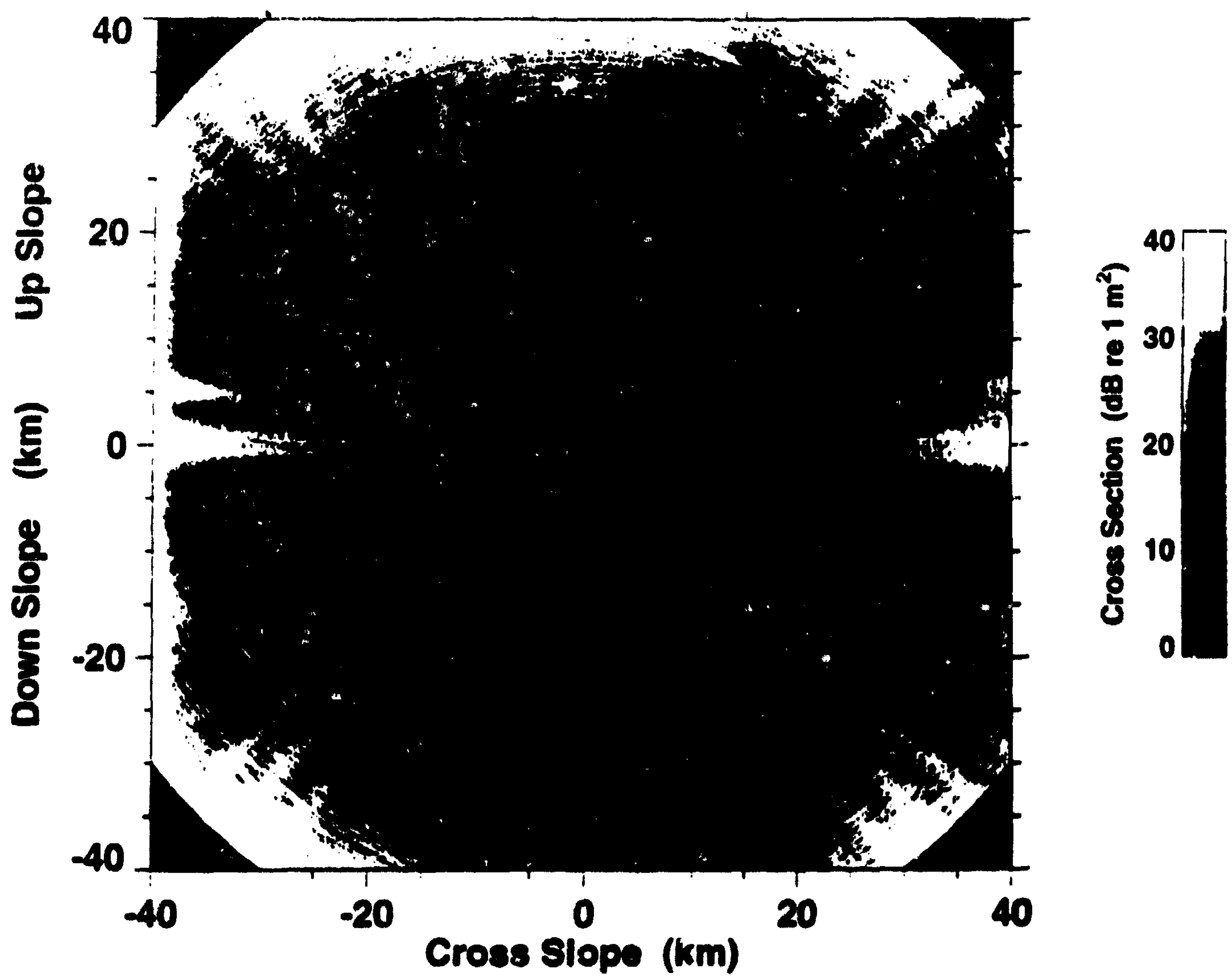
ACT1 Bottom Reverberation Level Simulation

Omni Source, Bottomed Array, 400 Hz
Includes Spherical Spreading Correction and Backscatter



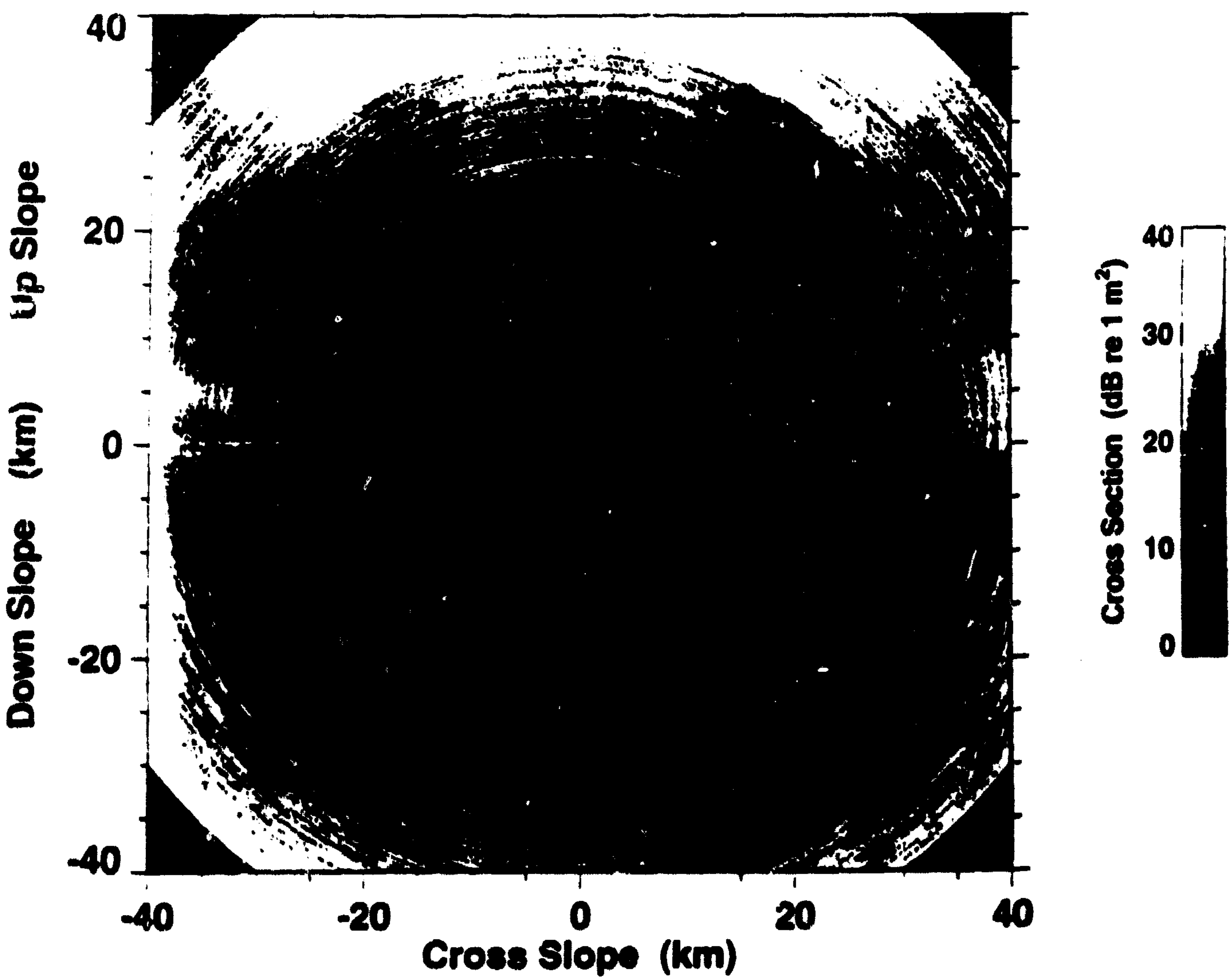
ARS-235-037-B

ACT1, Event mr1h13, Omni Source, Bottomed Array
1 Octave Band Centered on 400 Hz



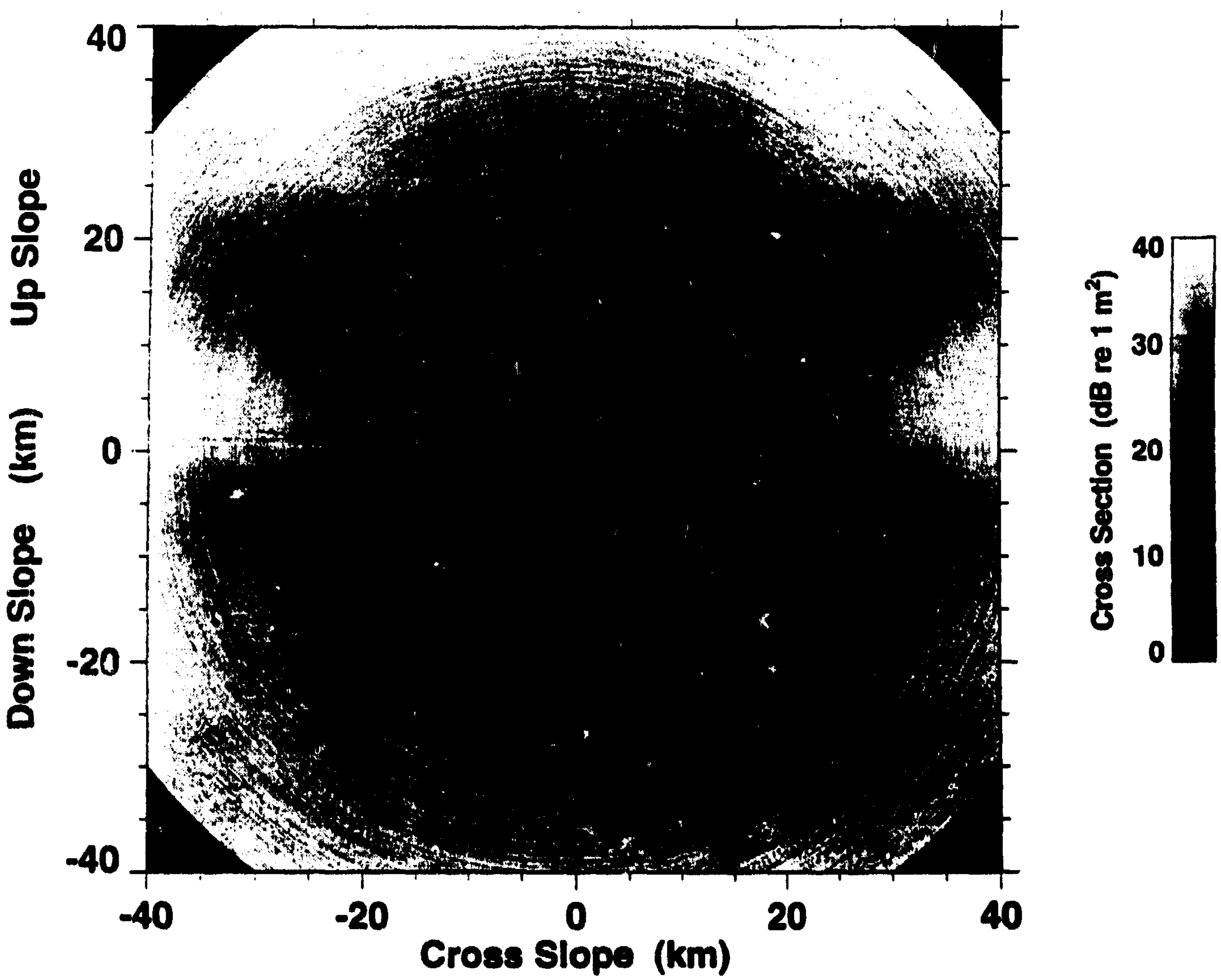
ARS-235-037-B

ACT1, Event mr1h13, Omni Source, Bottomed Array
1 Octave Band Centered on 200 Hz



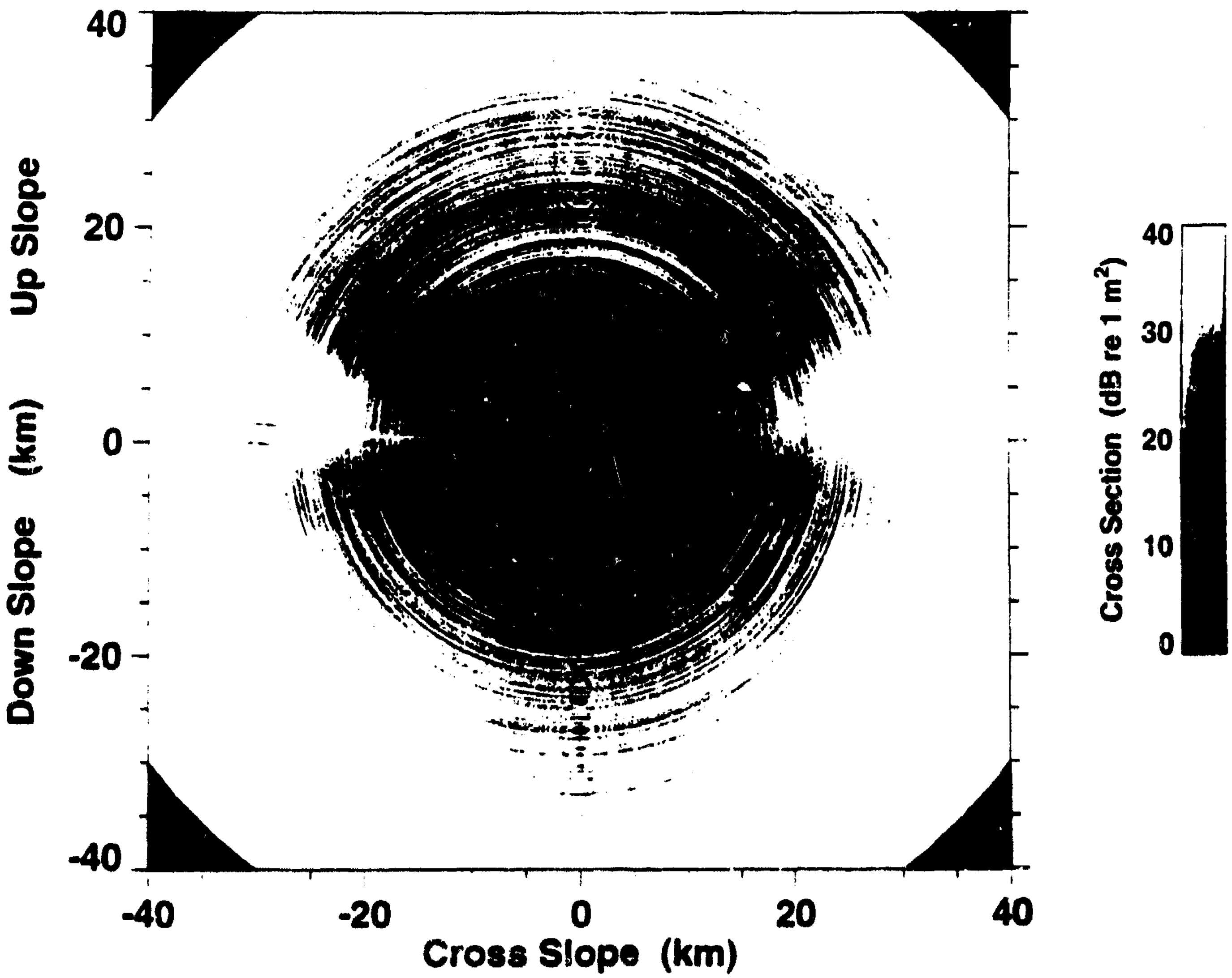
ARS-235-037-B

ACT1, Event mr1h13, Omni Source, Bottomed Array
1 Octave Band Centered on 100 Hz

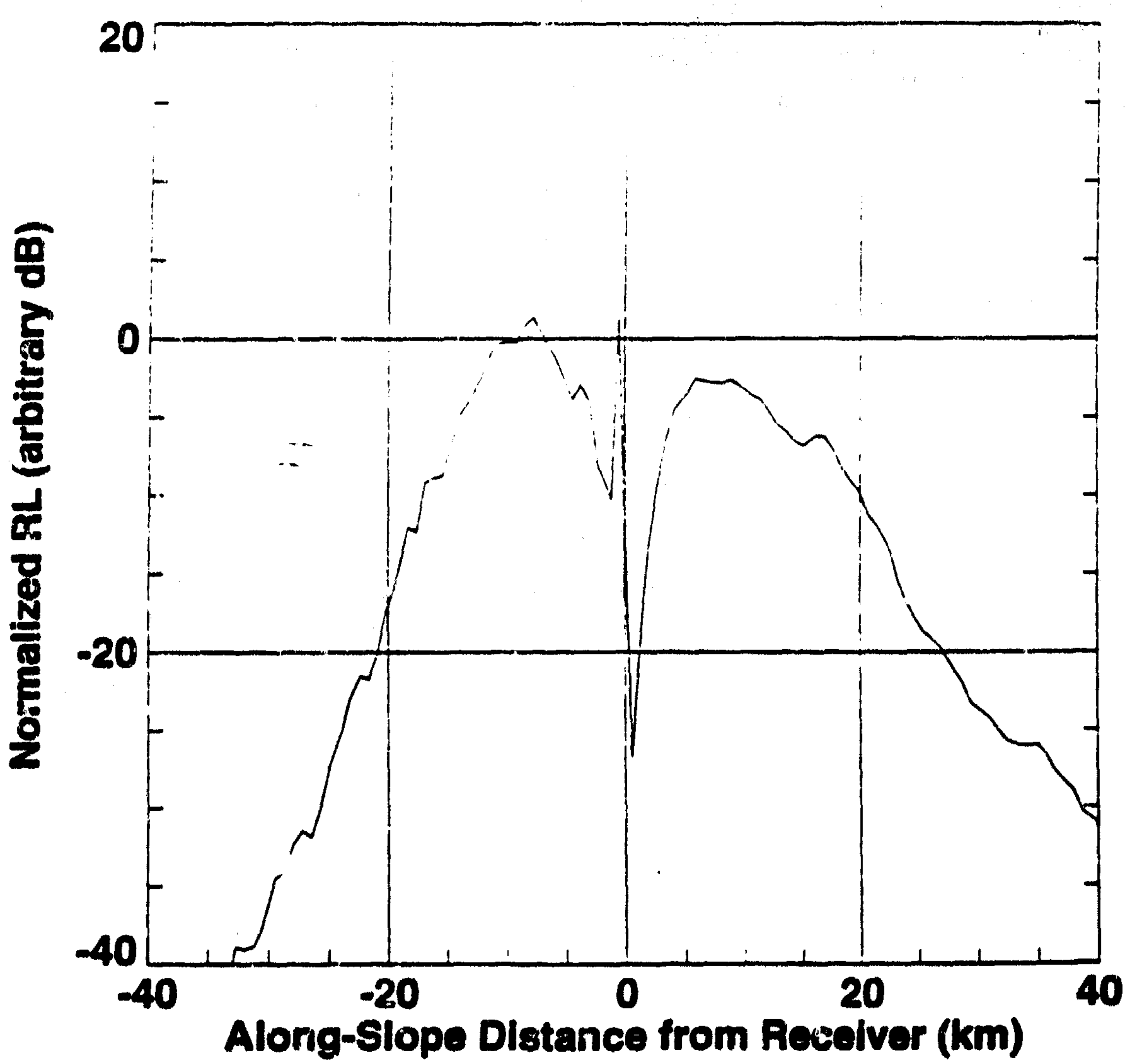


ARS-235-037-B

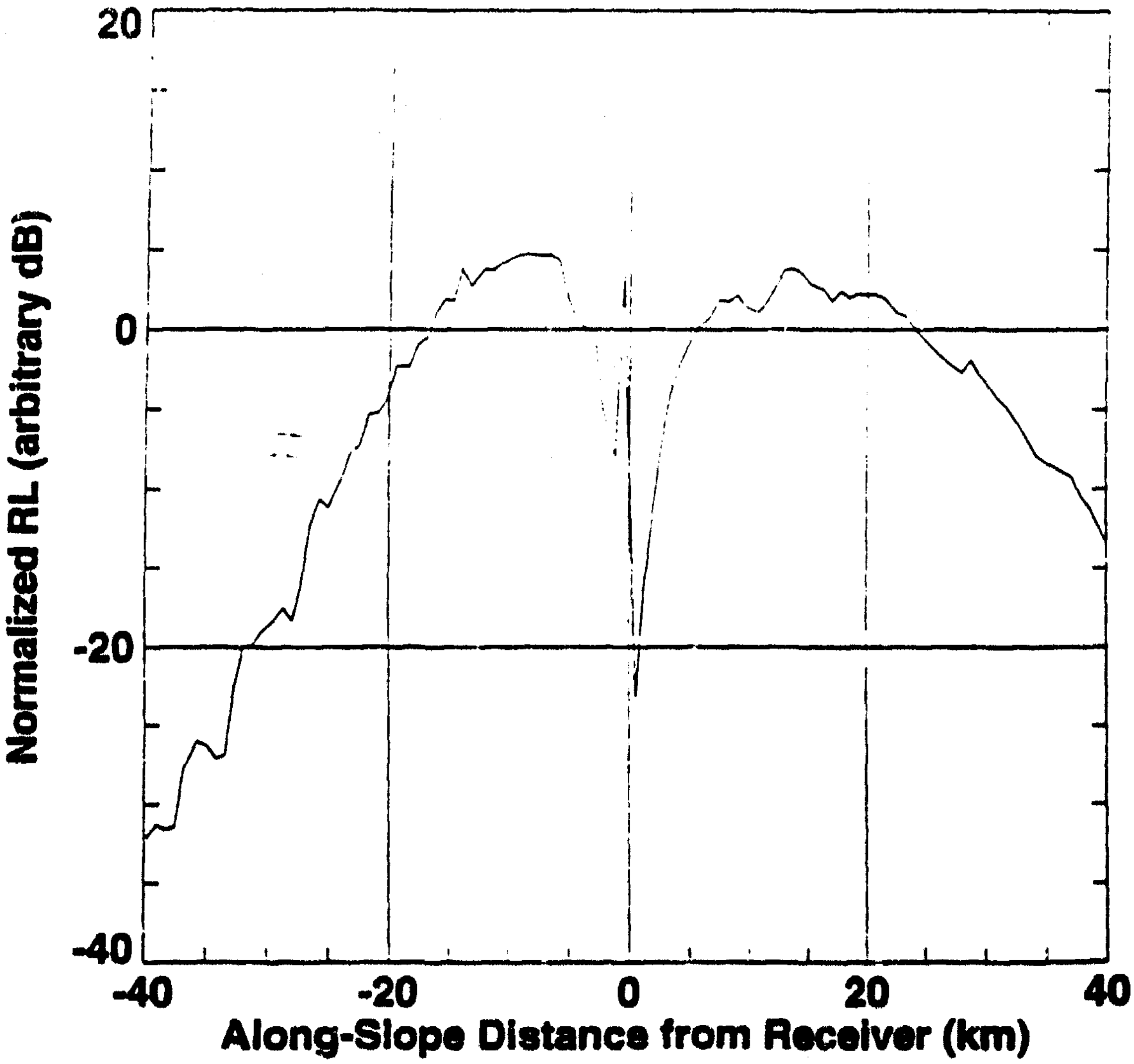
ACT1, Event mr1h13, Omni Source, Bottomed Array
1 Octave Band Centered on 50 Hz



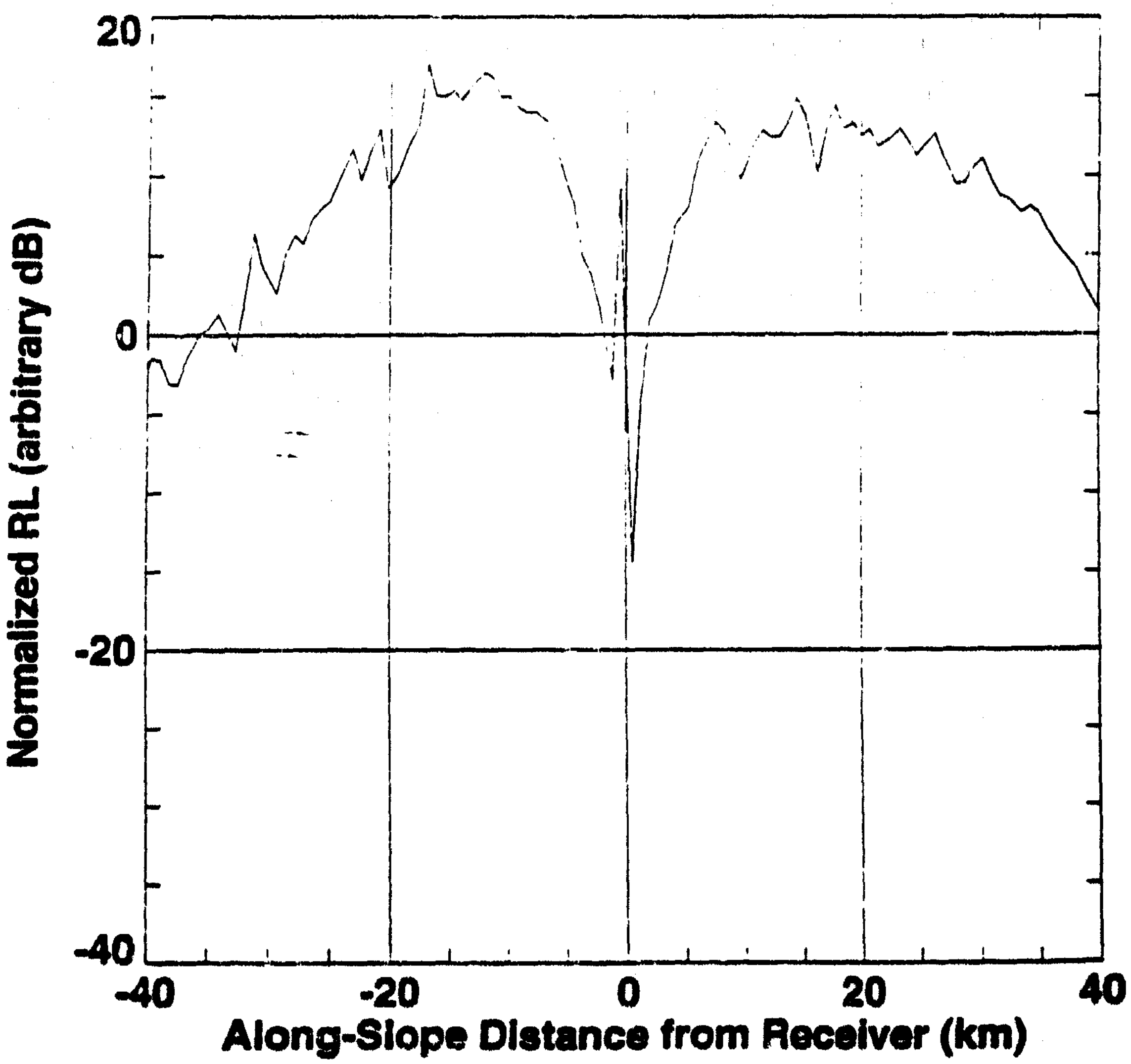
ACT1 Bottom Reverberation Level Simulation
Omni Source, Bottomed Array, 400 Hz
Includes Spherical Spreading Correction and Backscatter



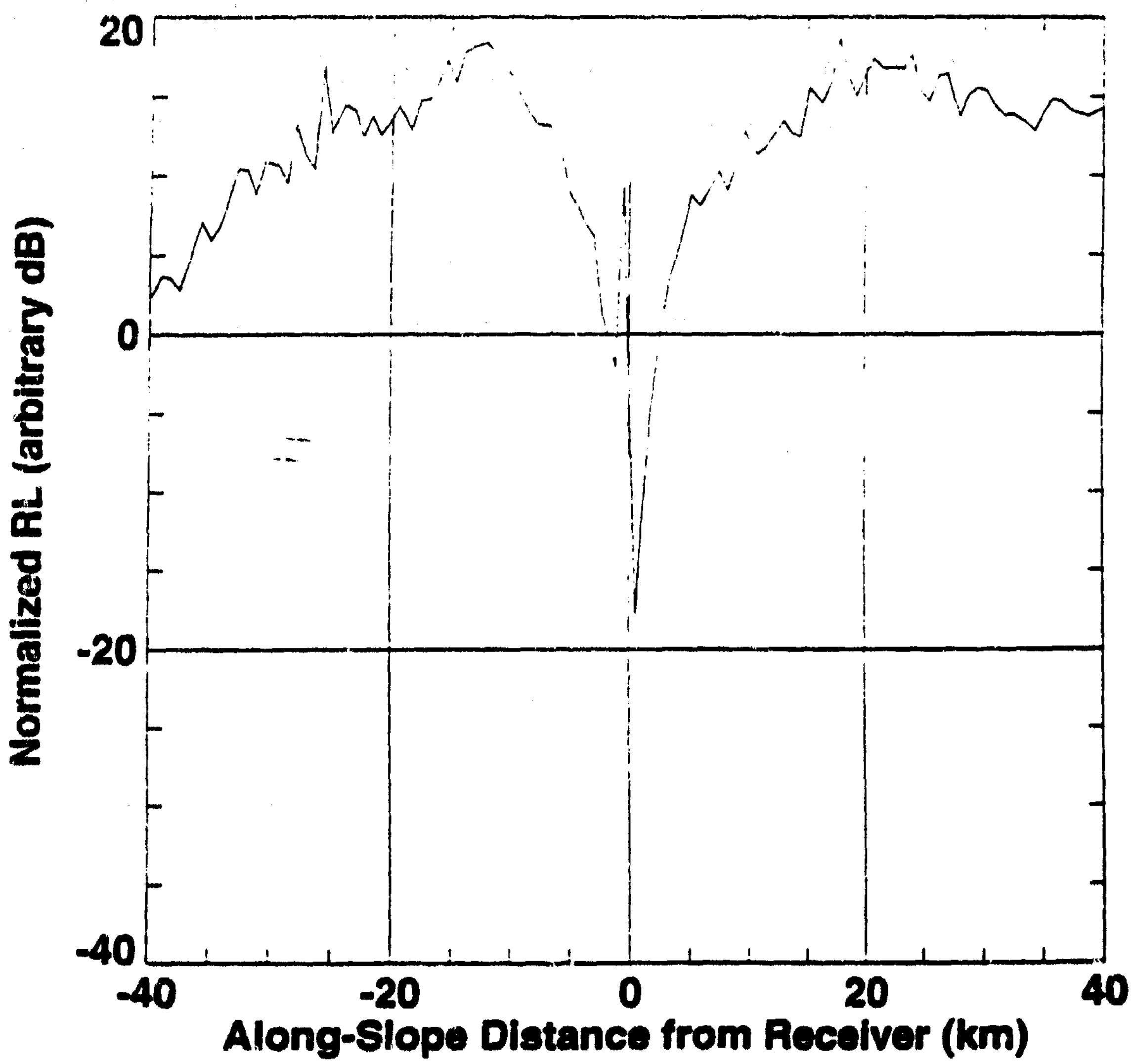
ACT1 Bottom Reverberation Level Simulation
Omni Source, Bottomed Array, 200 Hz
Includes Spherical Spreading Correction and Backscatter



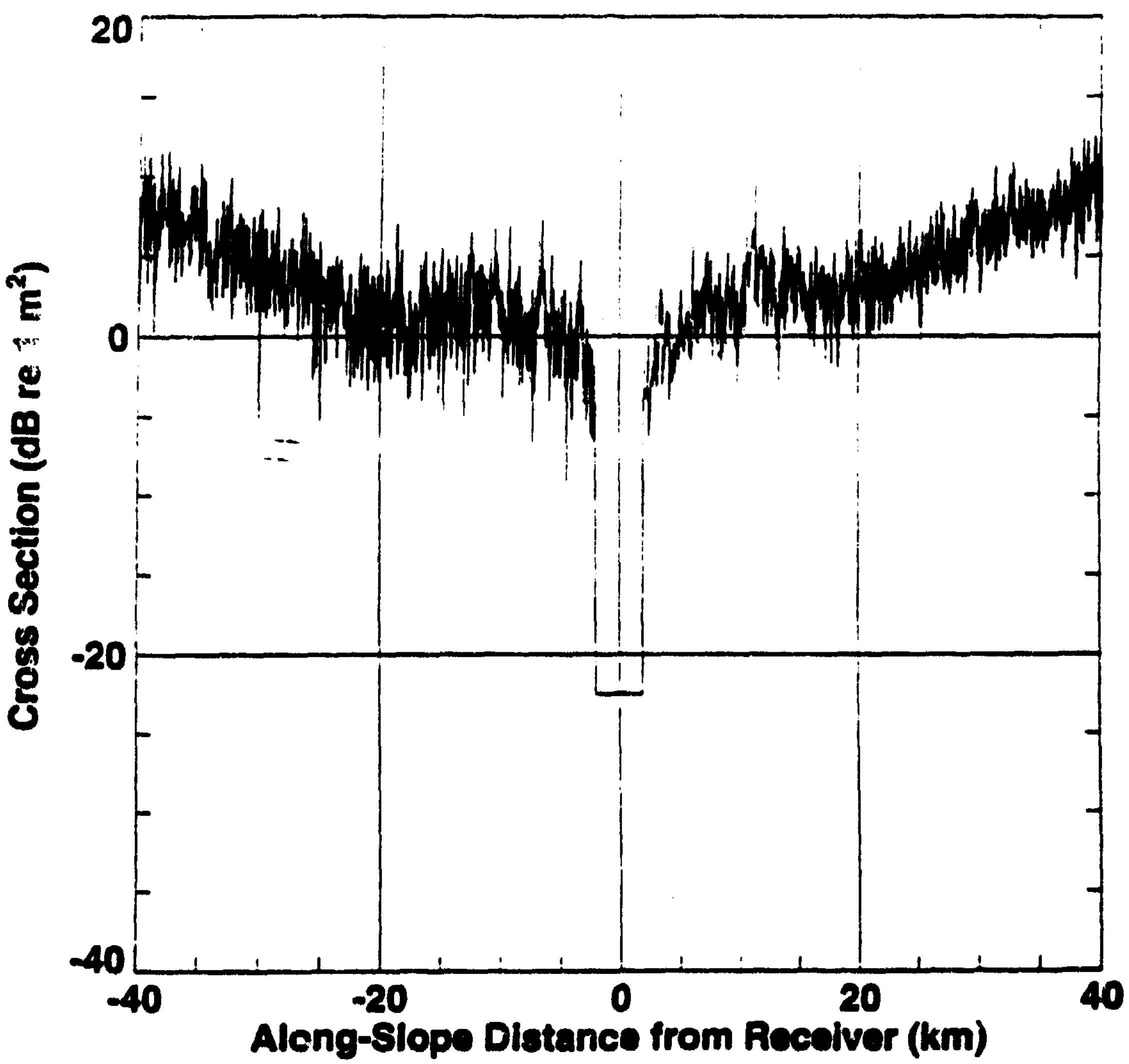
ACT1 Bottom Reverberation Level Simulation
Omni Source, Bottomed Array, 100 Hz
Includes Spherical Spreading Correction and Backscatter



ACT1 Bottom Reverberation Level Simulation
Omni Source, Bottomed Array, 50 Hz
Includes Spherical Spreading Correction and Backscatter



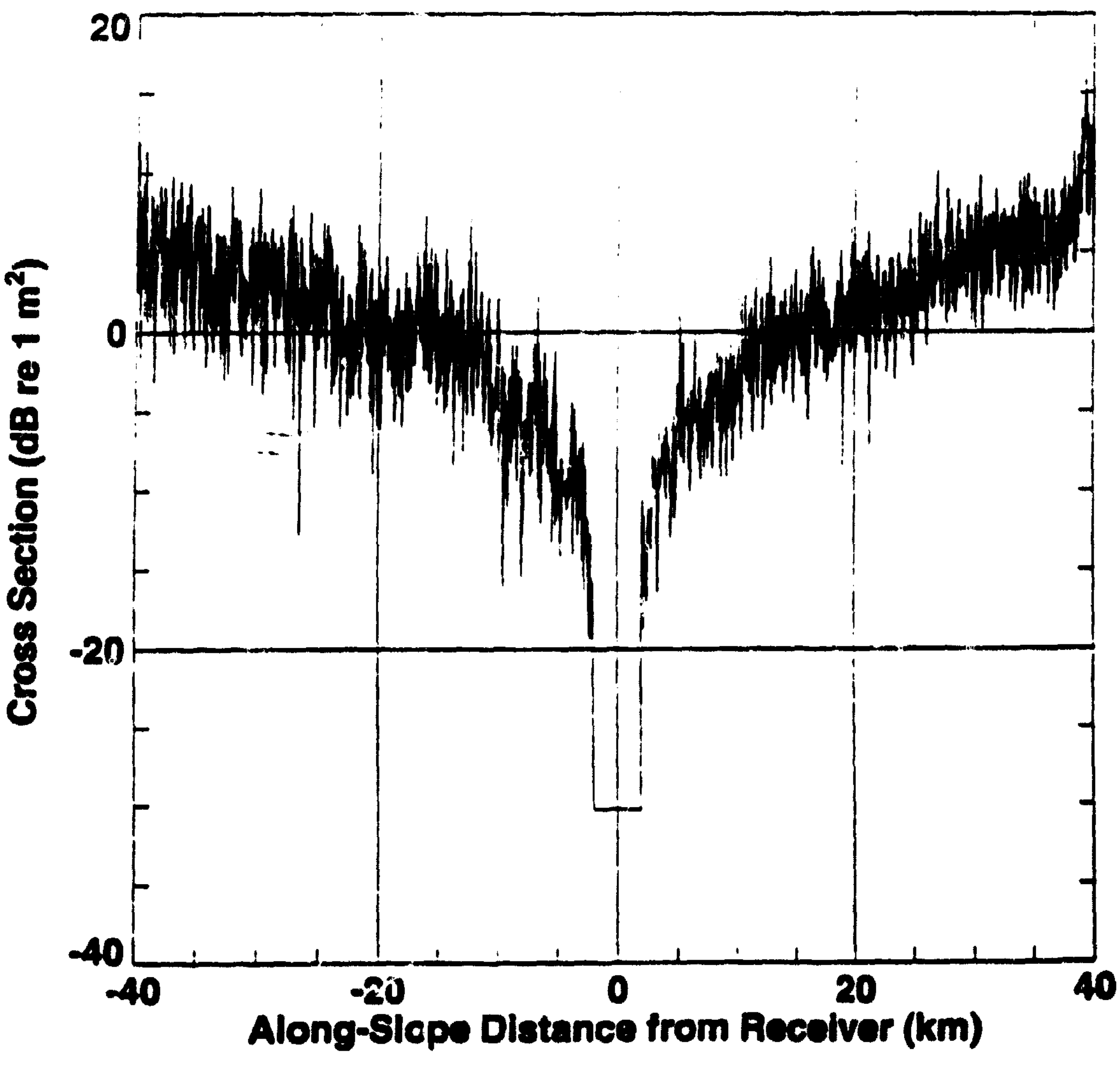
ACT1, Event mr1h13, Omni Source, Bottomed Array
1 Octave Band Centered on 400 Hz
Cut Through Image Along Slope



ACT1, Event mr1h13, Omni Source, Bottomed Array

1 Octave Band Centered on 200 Hz

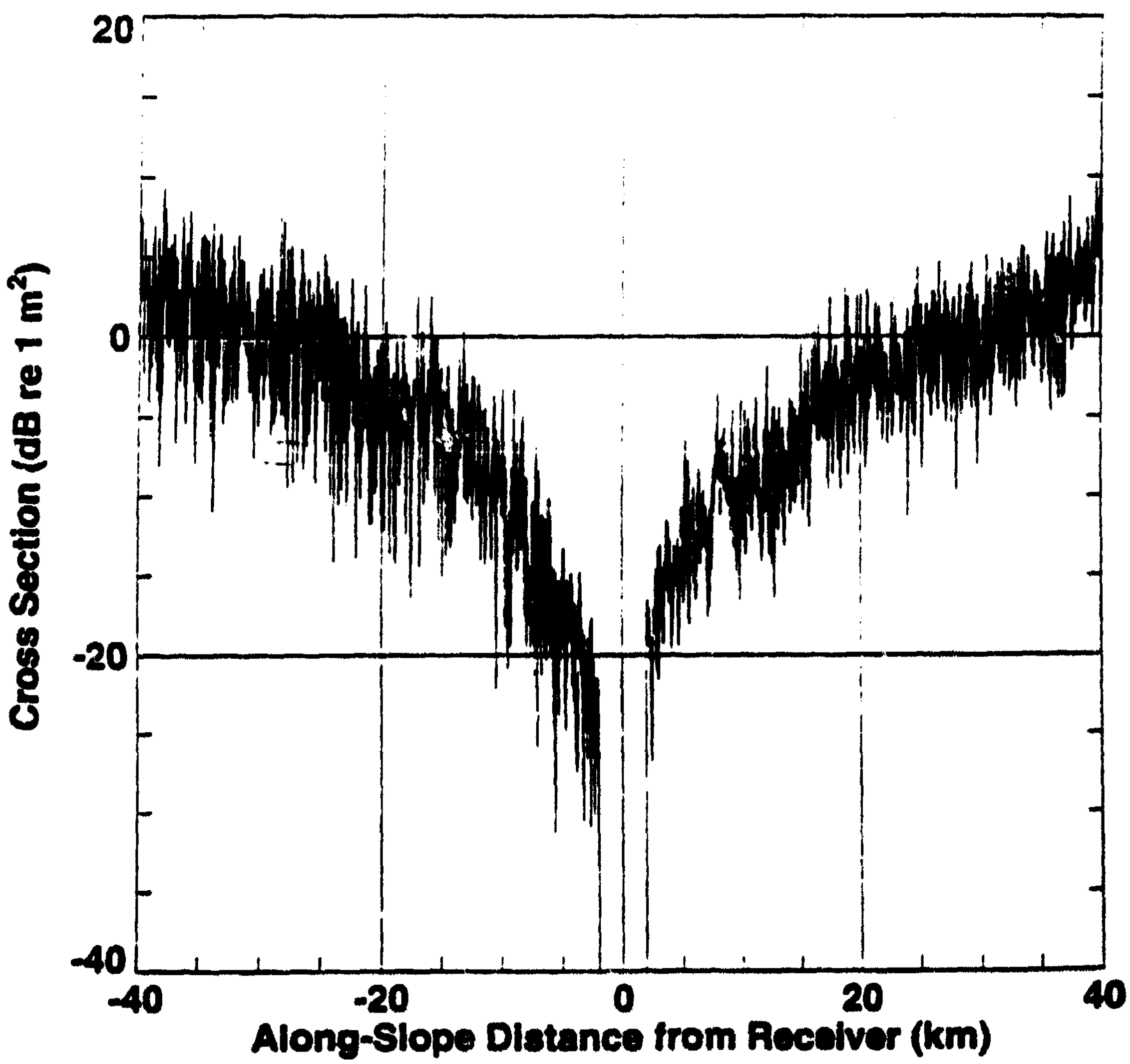
Cut Through Image Along Slope



ACT1, Event mr1h13, Omni Source, Bottomed Array

1 Octave Band Centered on 100 Hz

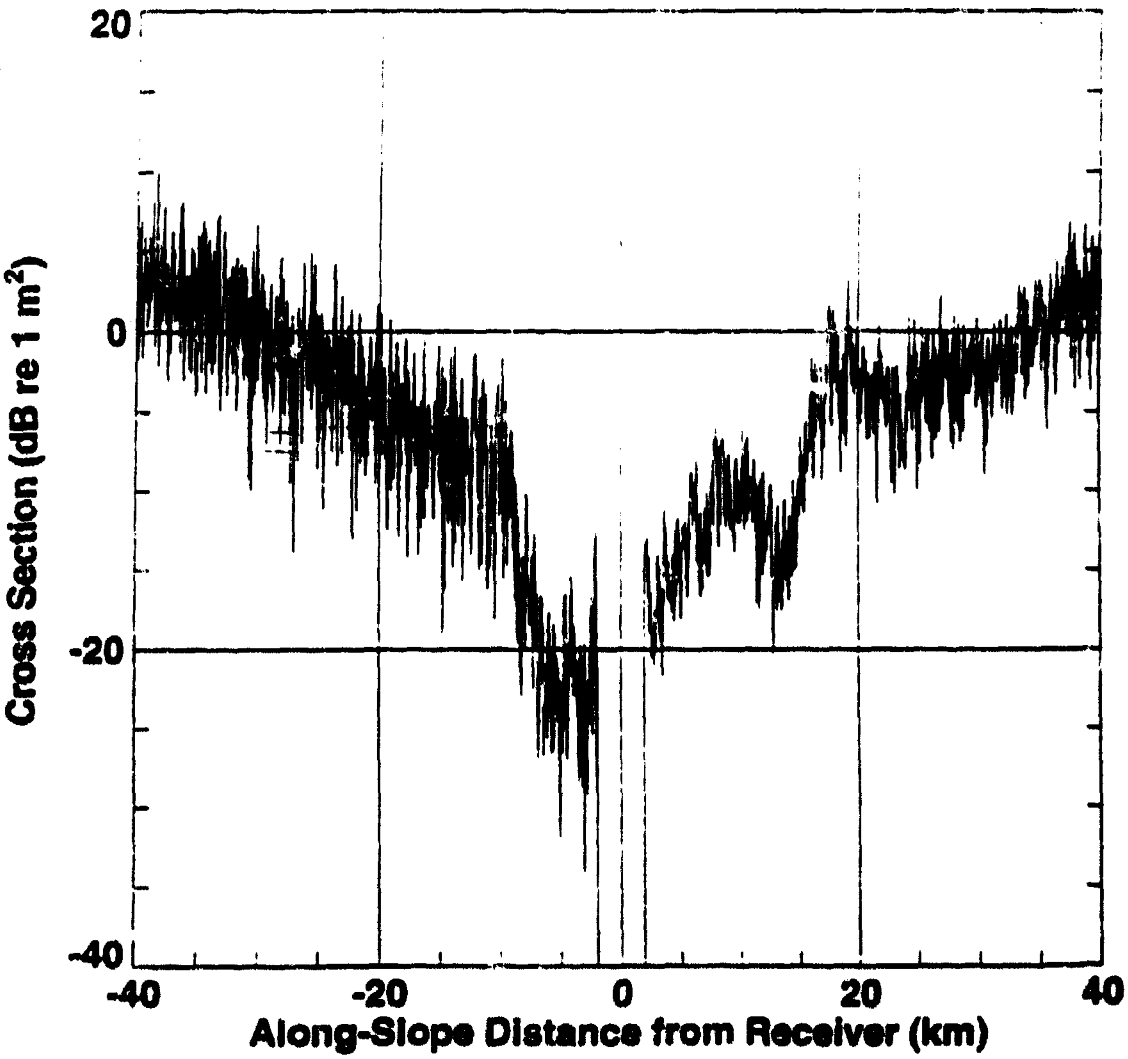
Cut Through Image Along Slope



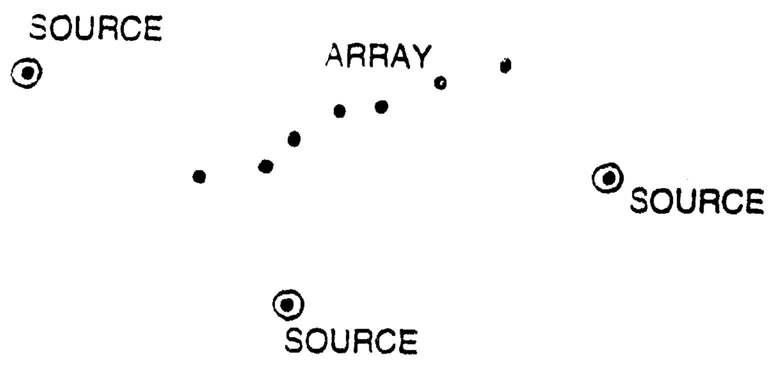
ACT1, Event mr1h13, Omni Source, Bottomed Array

1 Octave Band Centered on 50 Hz

Cut Through Image Along Slope



AUTO-COHERENCE WITH NEAR FIELD POINT SOURCES OF UNCERTAIN LOCATION



N phones

$\Rightarrow$ 2N + 2M unknowns

M sources

MN measured arrival times

For M $\geq$ 3, N large, there are many more measurements than unknowns

/ This can be solved in principal for all relative positions.

AUTO-COHERENCE WITH NEAR FIELD POINT SOURCES OF UNCERTAIN LOCATION (continued)

/ The obvious least error minimization approach is intractable:

a 12^{th} degree expression must be minimized in $(2N + 2M)$ dimensions.

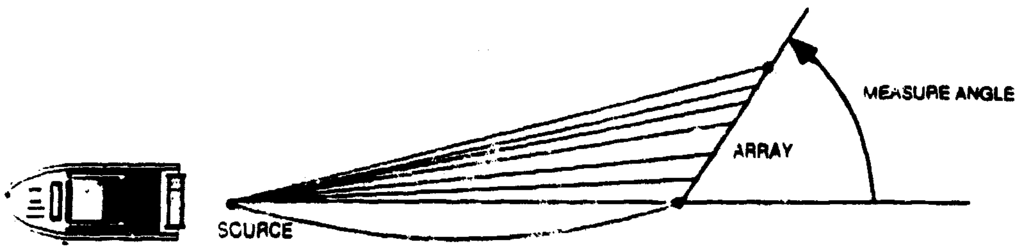
/ A unique reduced expression has been derived which is 6^{th} degree in 5 unknowns.

/ An algorithm has been developed and tested exploiting this expression which works with modest computational requirements.

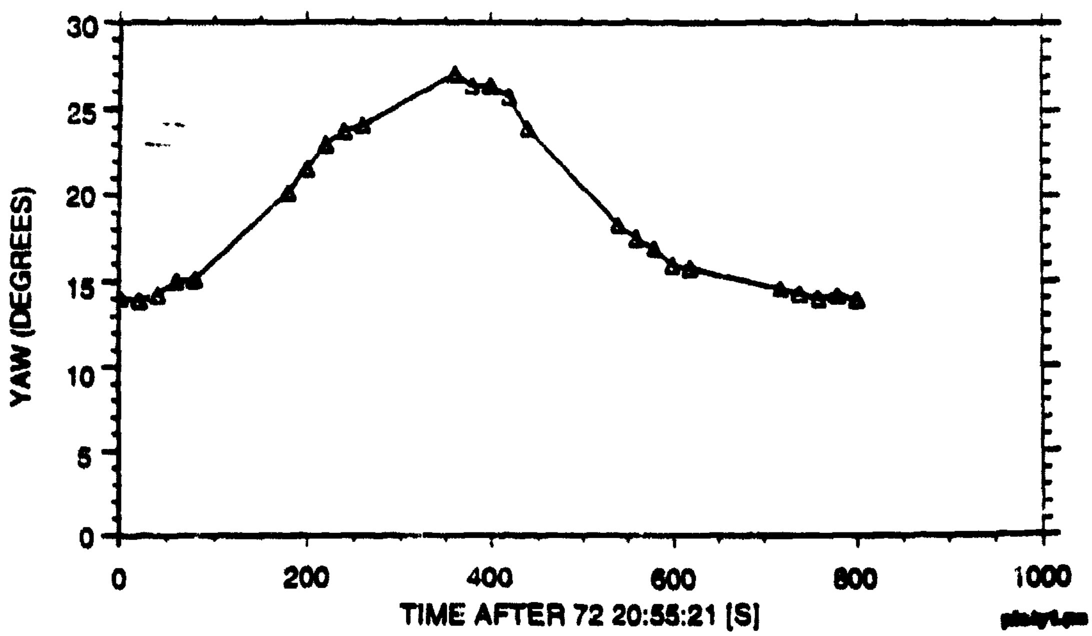
For ACT I (3 sources, 25 phones)

Computer	Run Time
HP 9000/735 SPARC Station 2	~ 20 minutes ~ 6 hours

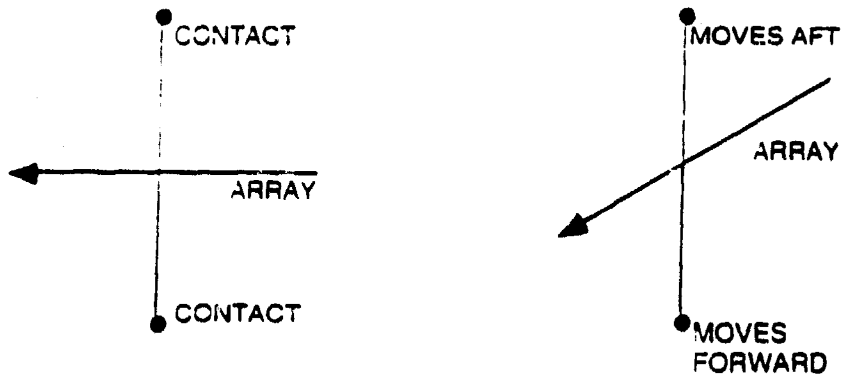
ARRAY YAW MEASURED DURING ARPA PHASE OF CST 7



- Limited sensitivity
- Cannot separate vertical and horizontal



ARRAY MOTION AND ITS EXPLOITATION



- This can cause many apparent moving contacts if not accounted for.

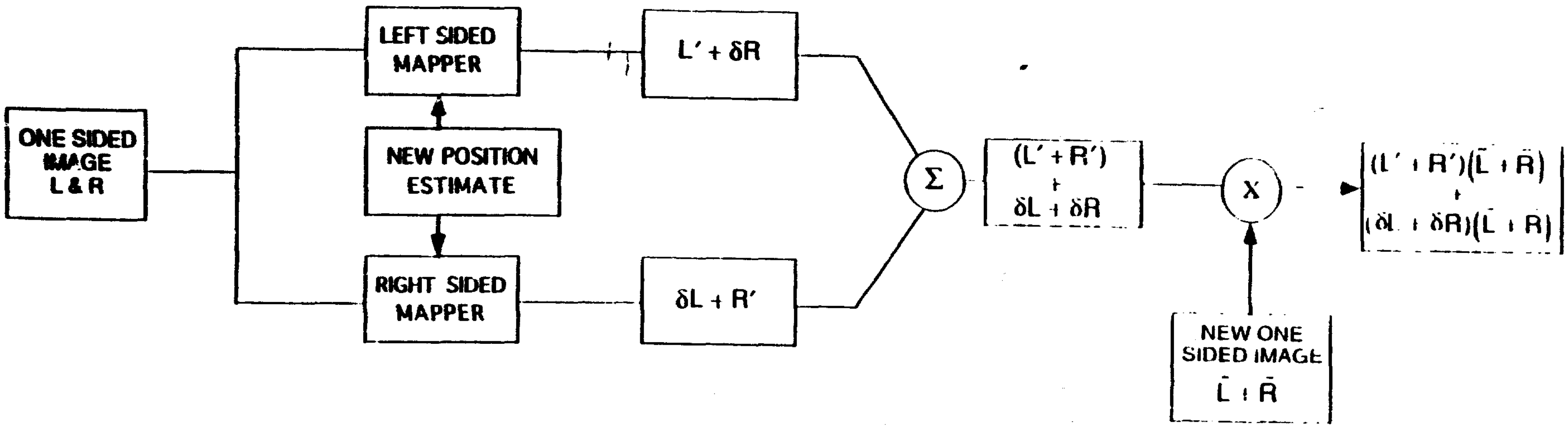
- This distortion can in principle provide

  / Actual array motion

  / Unambiguous and stationary left-right views.

ARS-235-037-B

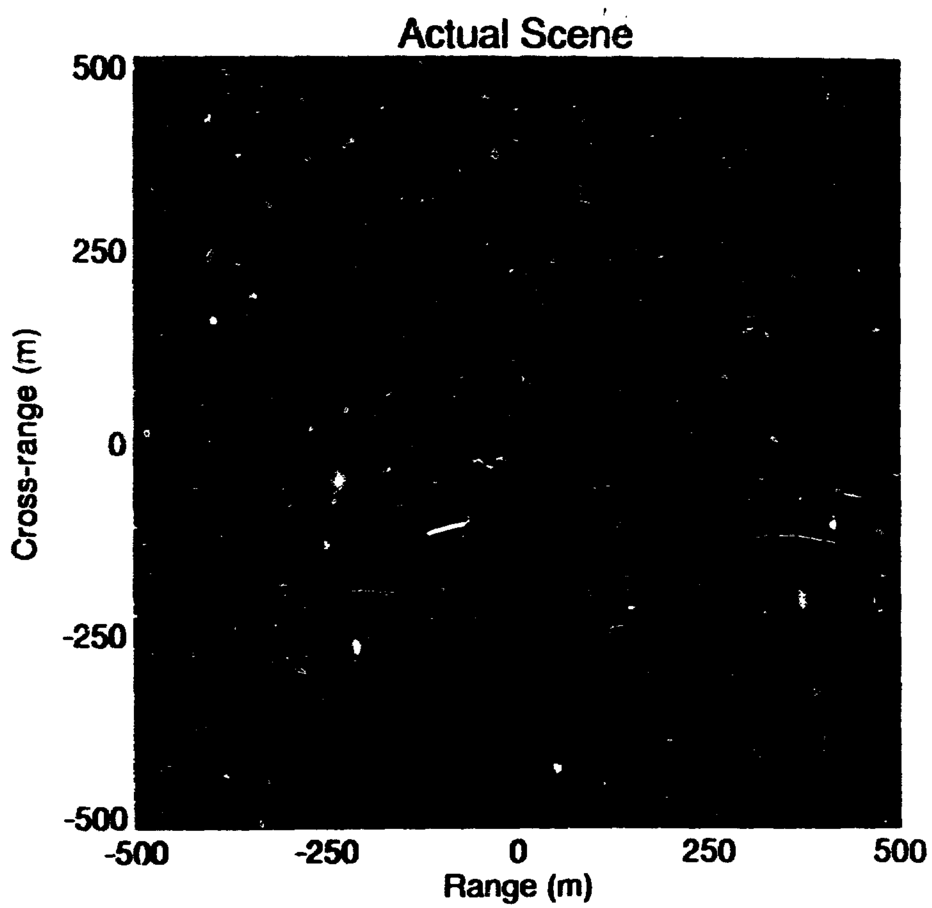
CONCEPT FOR MULTI-IMAGE REGISTRATION AND LEFT-RIGHT RESOLUTION

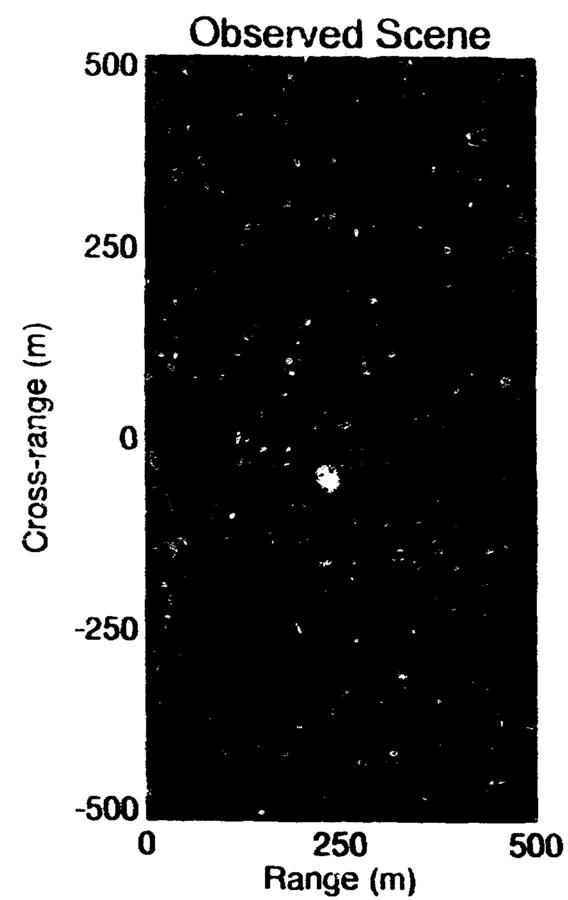


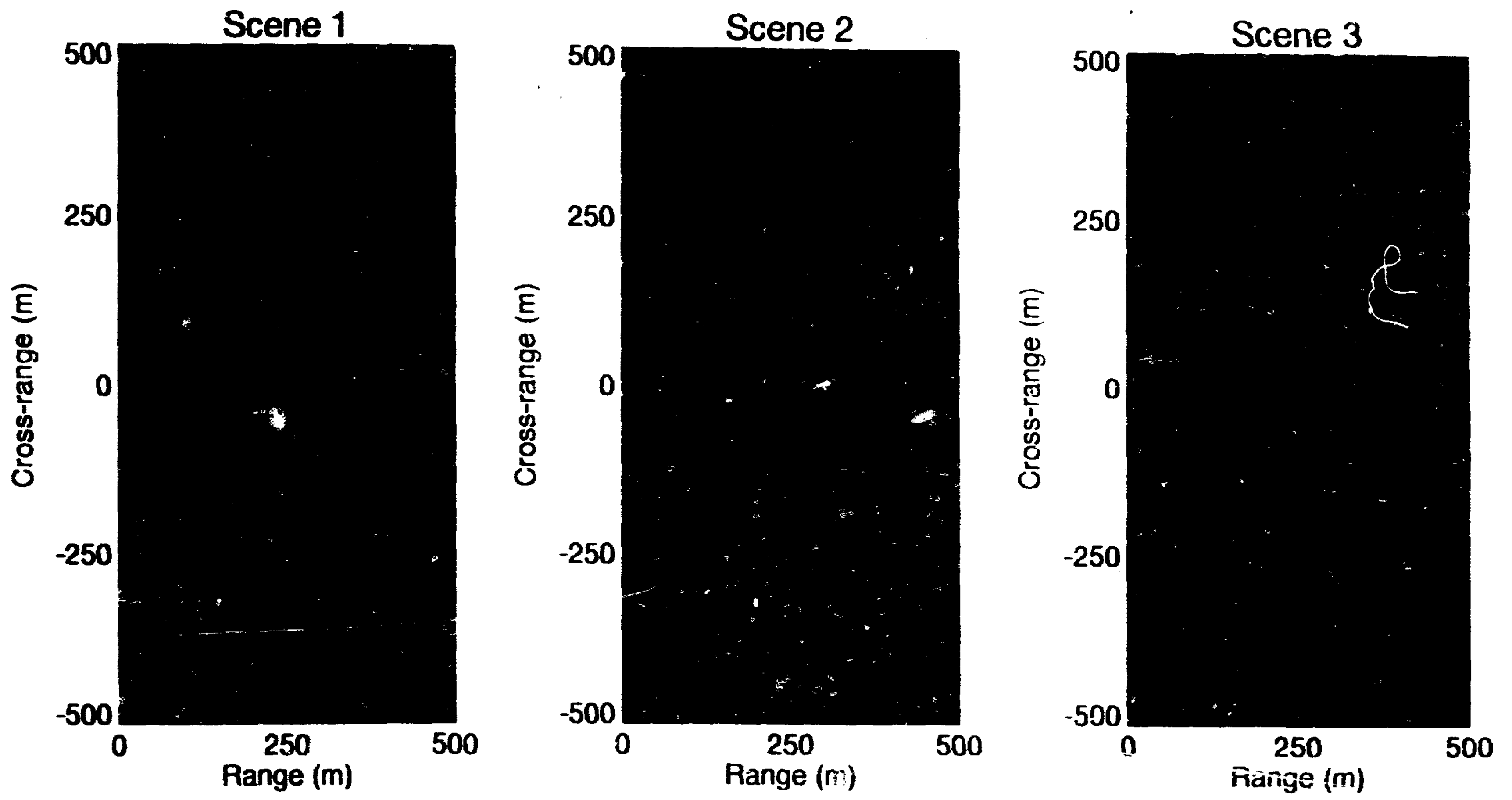
Map all images to a common frame:

Estimate Left = $\frac{1}{N}\Sigma\ (L + \delta R)$

Estimate Right = $\frac{1}{N}\Sigma\ (\delta L + R)$


Actual Scene
500
250
0
-250
-500
Cross-range (m)
-500
-250
0
250
500
Range (m)


Observed Scene
500
250
0
-250
-500
Cross-range (m)
0
250
500
Range (m)



Array Position: (0.0 , 0.0)

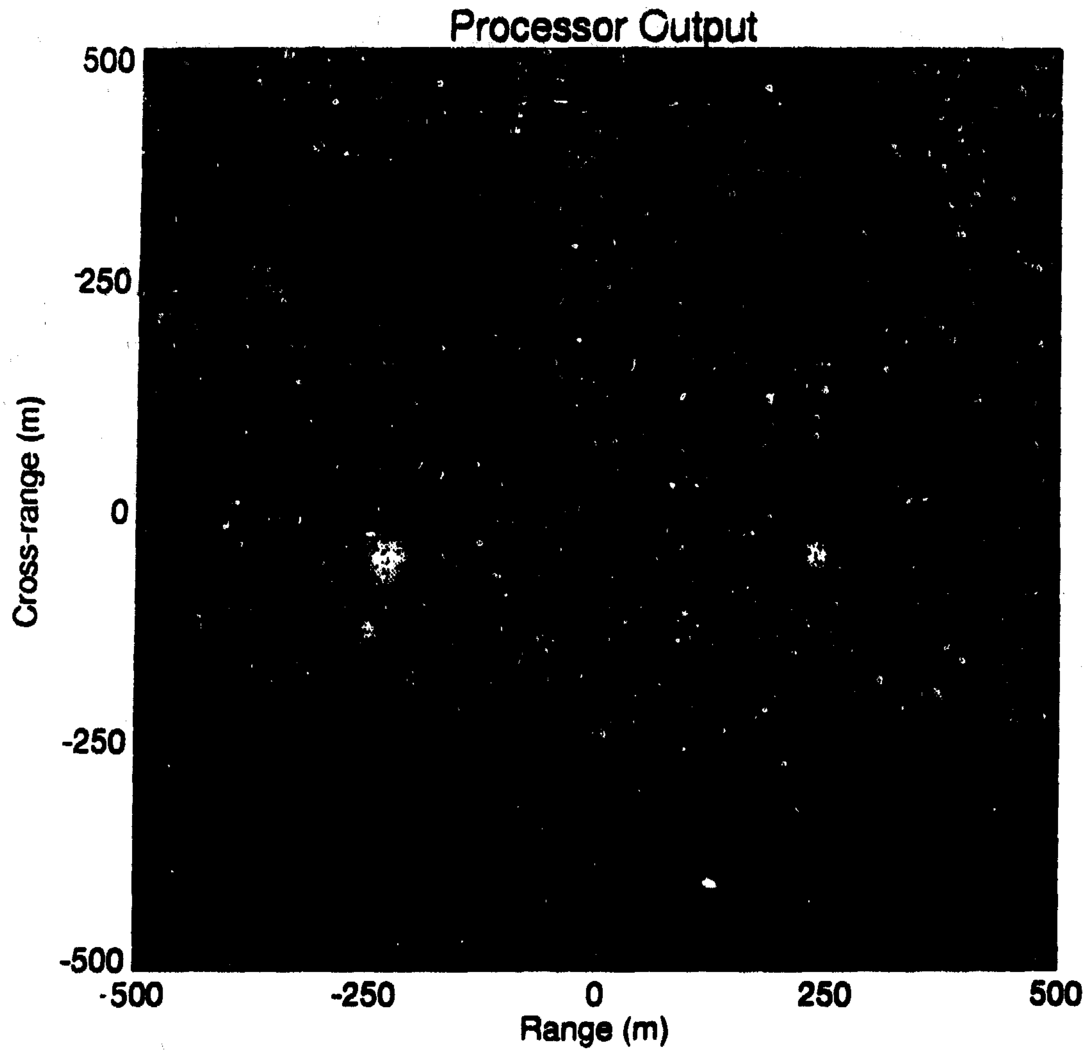
Array Angle: 0. deg.

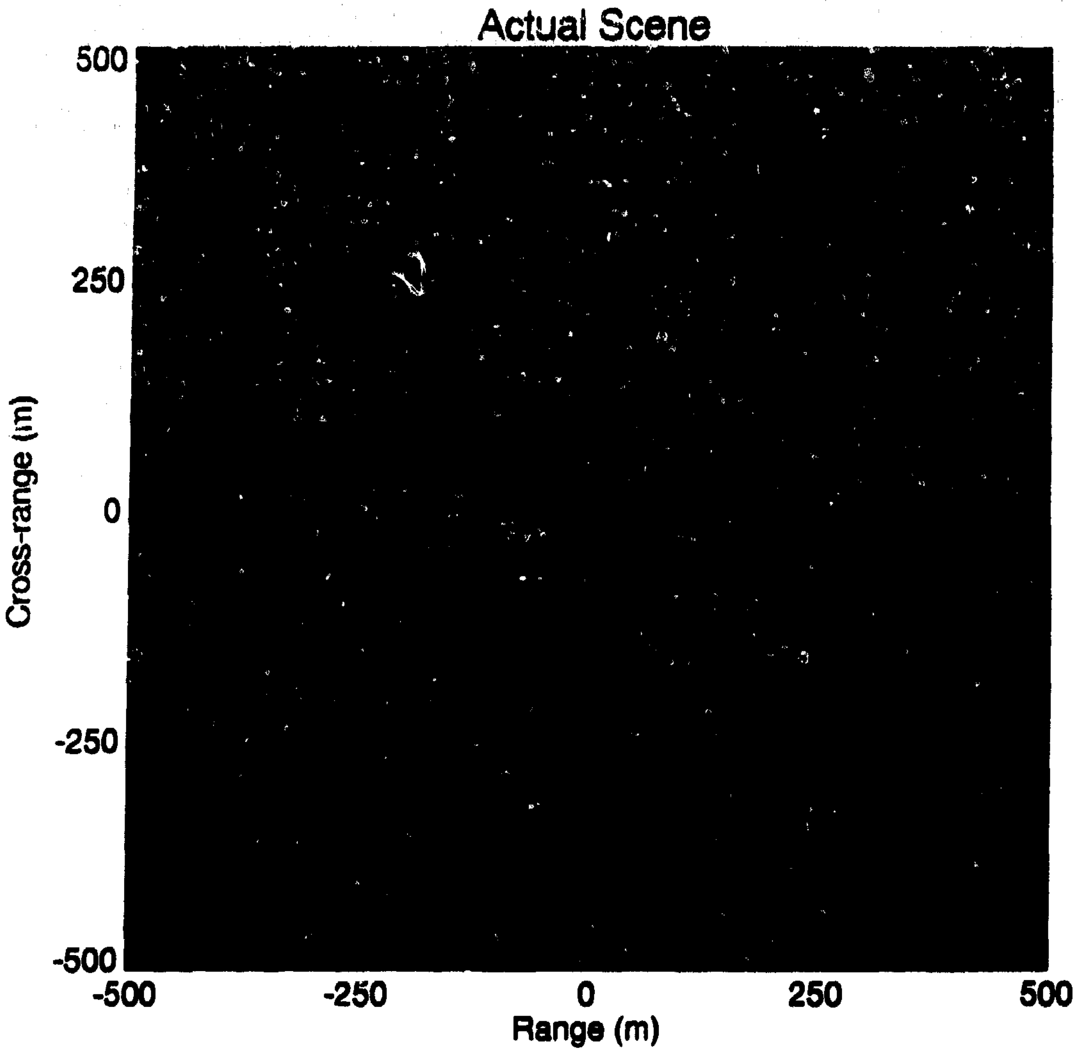
Array Position: (126.7 , 181.0)

Array Angle: 10. deg.

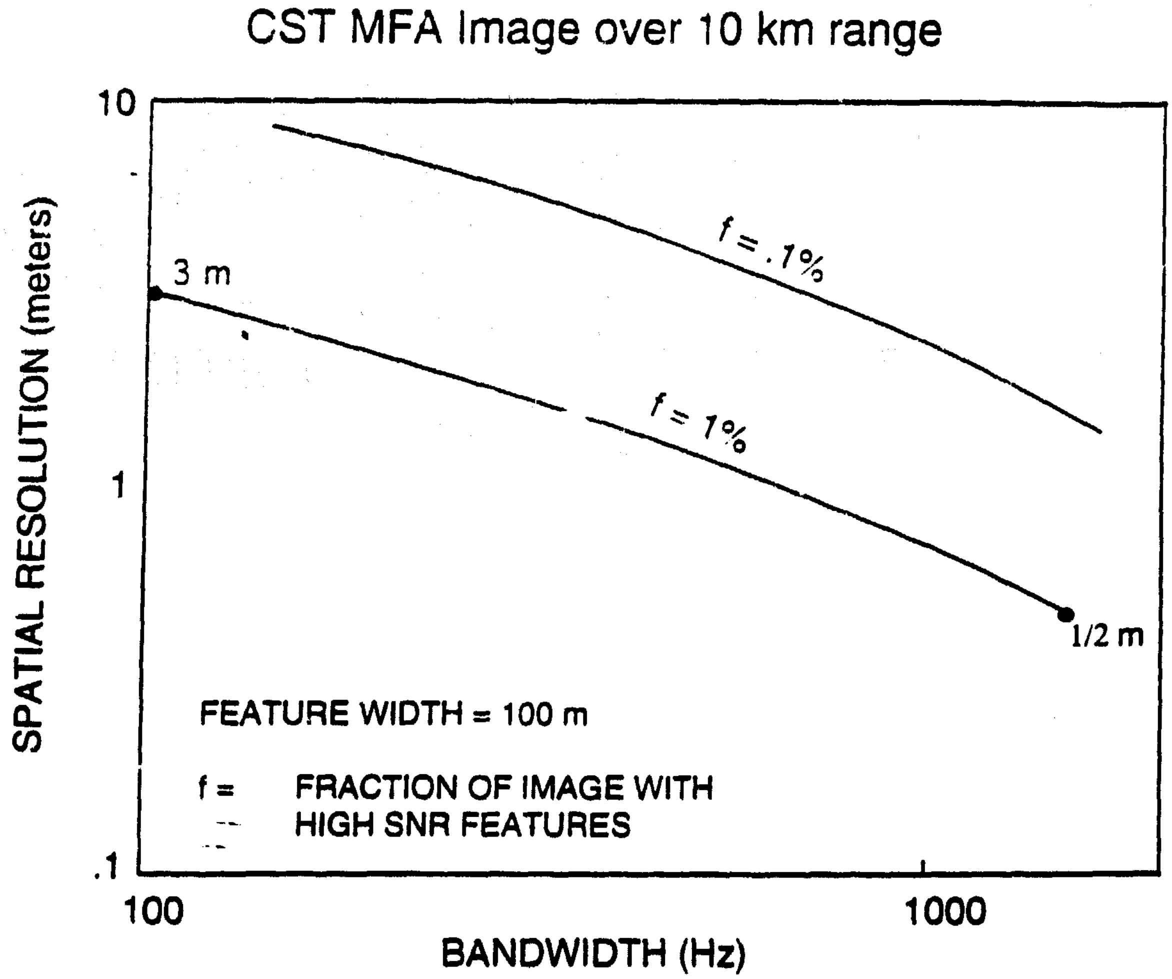
Array Position: (177.7 , 229.7)

Array Angle: 5. deg.


Processor Output
500
250
0
-250
-500
Cross-range (m)
-500
-250
0
250
500
Range (m)


Actual Scene
500
250
0
-250
-500
Cross-range (m)
-500
-250
0
250
500
Range (m)

SPATIAL RESOLUTION USING IMAGE REGISTRATION



WASP Processor Speed Coding Progress

Progress

- The MicroWay i860 processors are working correctly
- The VAST auto-vectorizer for C now produces correct code
- Image code is being reworked to take advantage of the pipelined architecture of the i860 chip. Time to create an ACT I image* is estimated at 4.8 minutes. (37% duty cycle)

* 25 sensors, 3.2K sps, 80Km range, 462 beams

Code Sections and Timings

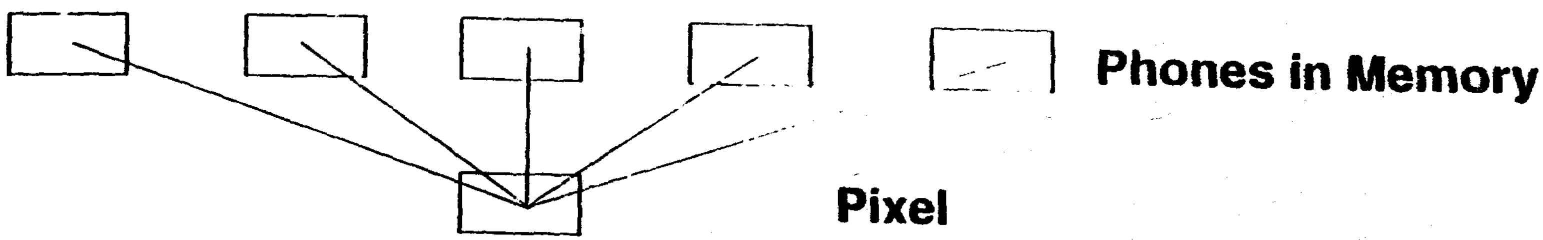
Section	Achieved to Date	Expected
Read Data from Disk	11 sec	4 sec
Index Creation (time delays)	71 sec	45 sec
Image Creation	193 sec	120 sec
Image Output	3 sec	3 sec

288 sec = 4.8 Minutes

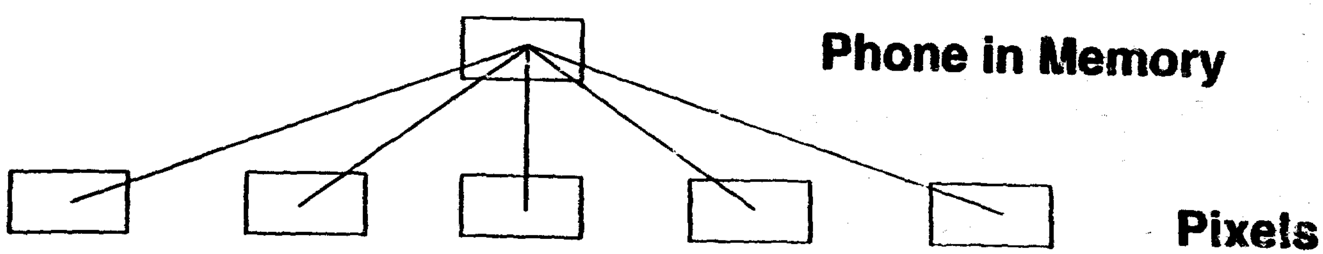
Code Vectorization

Previously, each pixel was calculated individually. Since the phone data is very large, each pixel would result in widely varying memory locations being accessed. The new method determines the contribution of each phone for an entire range-bin row of pixels before moving on to the next phone. The large vectors created by this change allow the procesor pipeline to be filled more often, without memory wait states as phone data is retrieved from non-cache system memory.

Before:



After:

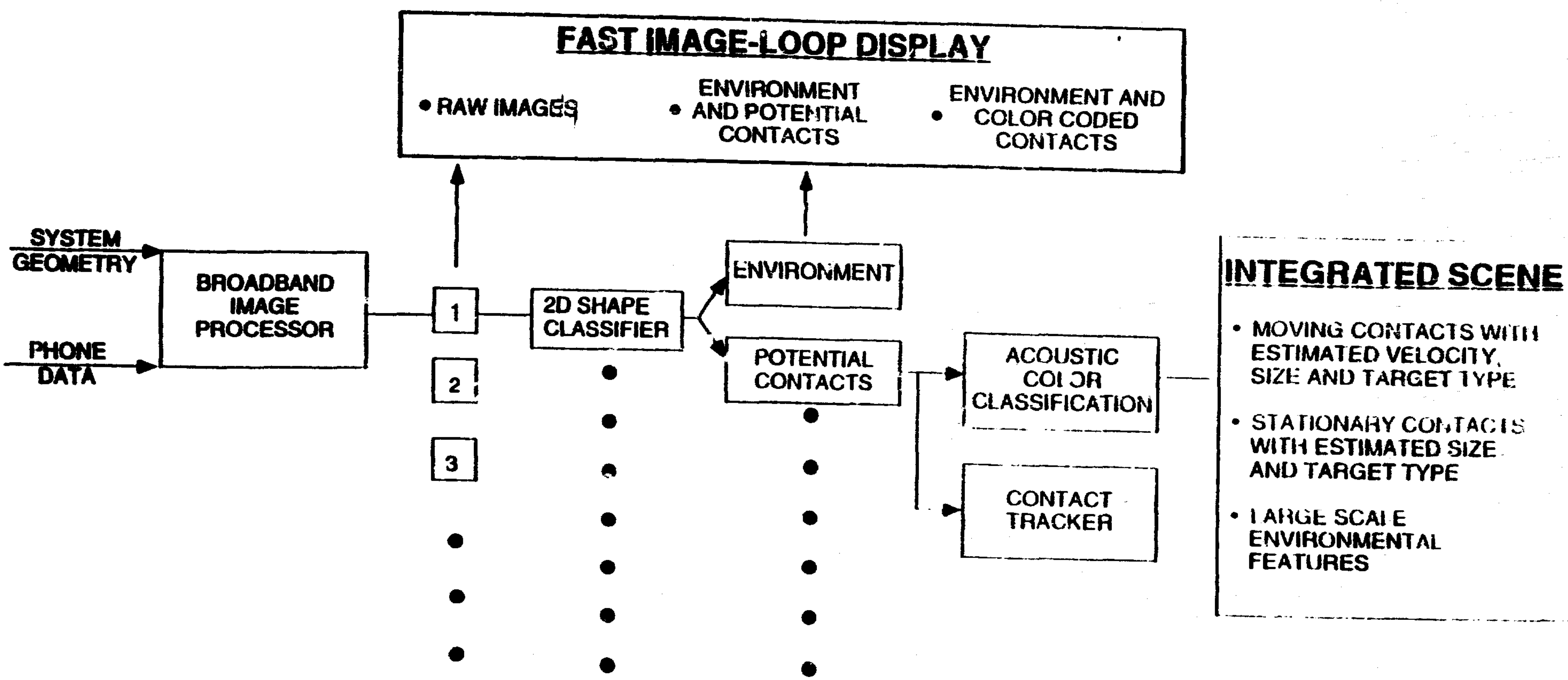


COMPARISON OF PROCESSORS

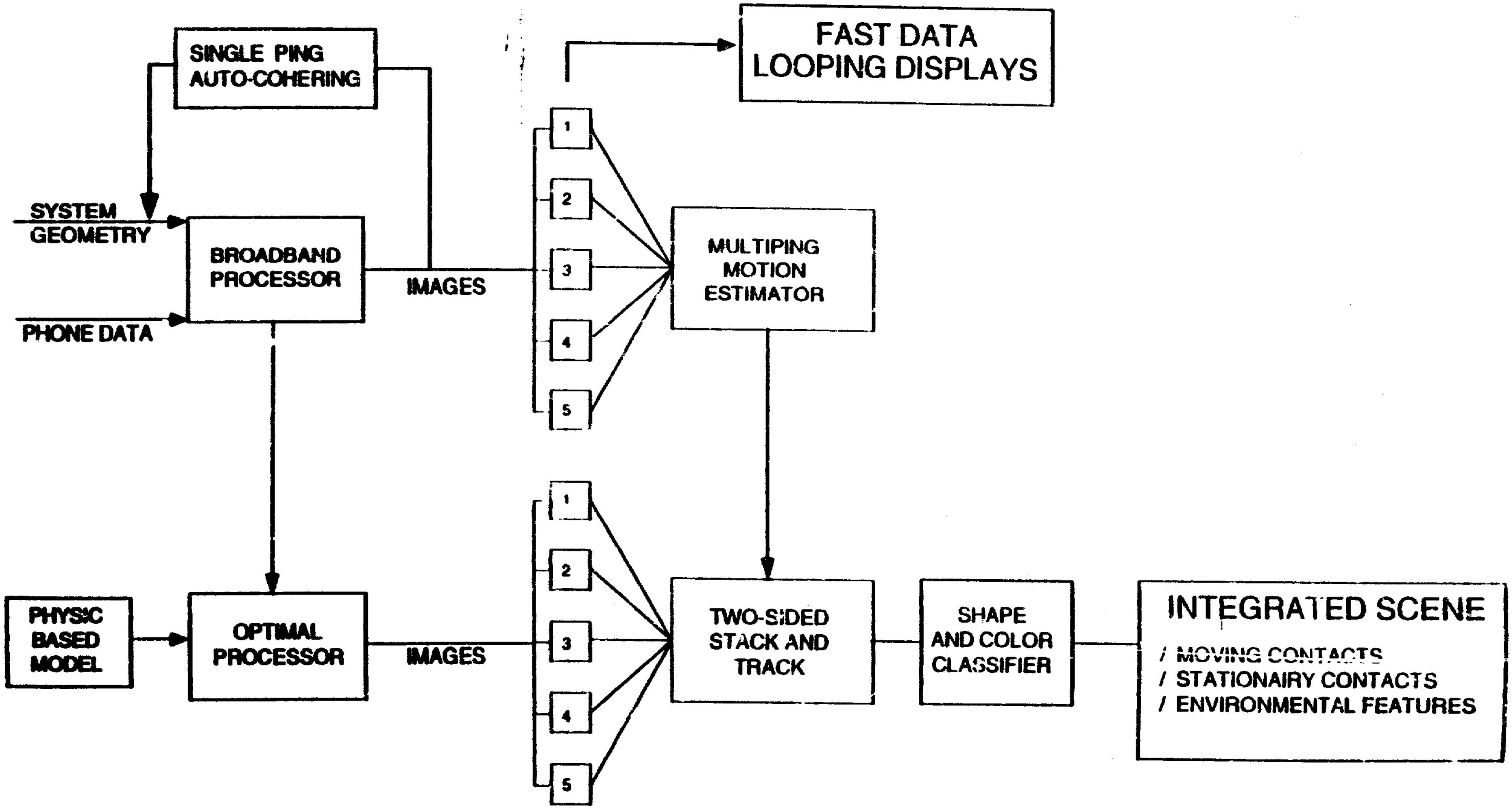
SUN SPARC II	HP 9000 735 CRX	MICROWAY* 5 X i860
47 min (3.8% duty cycle)	10.8 min (16.5% duty cycle)	4.8 min (37% duty cycle)

* Estimate only, processor not yet fully operational and tested

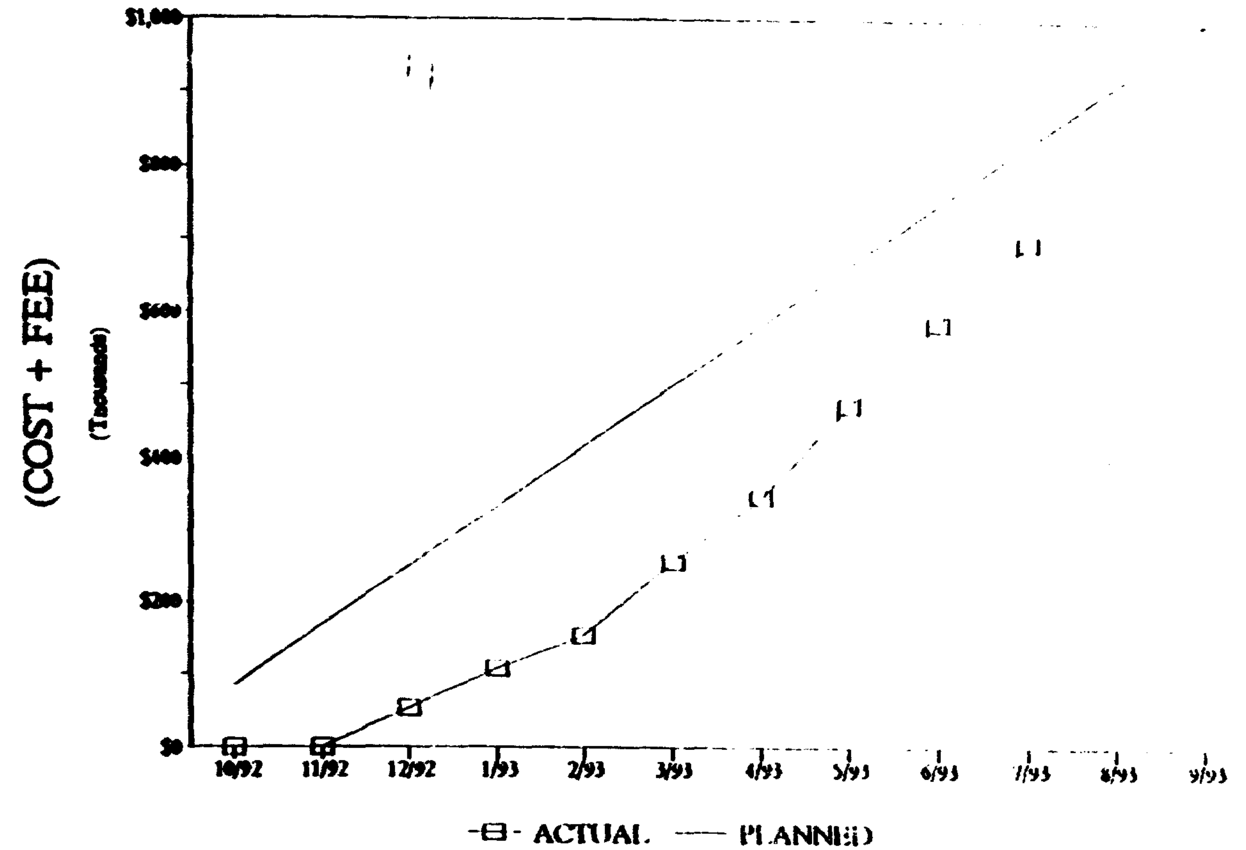
CONCEPT FOR OPERATIONAL PROCESSOR



CONCEPT FOR ADVANCED CAPABILITY PROCESSOR



CUMULATIVE COST EXPENDITURES
JOB CODE: 3235XXX - CLIN 0003



Areté Engineering Technologies Corporation

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4 October 1994

Dr. William Carey
Advanced Research Projects Agency
Maritime Systems Technology Office
3701 North Fairfax Drive
Arlington VA 22203-1714

Reference: MDA972-91-C-0063

Dear Bill:

Upon review of our contract files we found that copies of some quarterly reviews for CLIN 0003 on the above referenced contract were not forwarded to your office. For your convenience I have enclosed the following reports:

1) "High Resolution Bottom Characterization" (ARS-235-021-B), dated 4 May 1993.

2) "ARPA Progress Report" (ARS-235-037-B), dated 26 August 1994.

3) "Broadband Low-Frequency Acoustic Imaging" (ARS-235-049-B), dated 21 December 1993.

Copies of the remaining quarterly reviews for CLIN 0003 have been delivered; "DARPA Quarterly Review" (ARS-235-001-B), dated 6 January 1993, and "Nearfield Imaging During CST 7, Phase III (U)" (AS-93-0009.0), classified SECRET and dated 1 March 1994.

If you have any questions, or require more information, please call me at (619)450-1211.

Sincerely,

D. W. Miklovic, Ph.D.
Vice President

DWM:dj
SD-093

Enclosures: As stated above

cc: See Distribution

94-J-473

<u>Distribution</u>

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